

EQUINE DENTISTRY

THIRD EDITION

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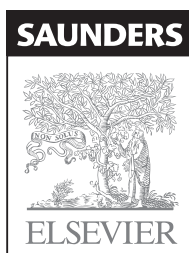
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Preface and Acknowledgments

Producing this textbook required the support, encouragement, and patience of our families and the contribution of many colleagues – all experts in the various aspects of equine dentistry. We are indebted to the editors and staff of Elsevier for helping us produce this book and, in particular, to Louisa Welch for keeping us organized and on time with production.

As editors, the three of us have had a keen interest in equine dentistry from the beginning of our careers and have enlisted the help of many others who share this interest to produce this book. We believe this text to be a compilation of a comprehensive range of topics discussed by the most world renowned experts in the field of equine dentistry. We thank many colleagues, who although are not contributing authors, have contributed to *our* knowledge as authors. We also acknowledge the horses and their owners that provided the experiences contributing to our understanding of equine dentistry.

The first edition of Equine Dentistry was published ten years ago. Since that time, the field of equine dentistry has undergone tremendous changes, with major advances in our understanding of equine dental anatomy and disease and also more general advances in equine analgesia and anesthesia, diagnostic imaging, and dental surgery. Additionally, the expansion of equine dental research has allowed us to use scientific evidence in developing diagnostic, prophylactic, and treatment options for our equine patients.

Publication of this present text now provides the most up-to-date information about equine dentistry. This book is comprised of chapters written by veterinarians with diverse interests in the field of equine dentistry and so, should

attract a diverse audience. We hope this information is useful to veterinarians in clinical equine practice and research, veterinary students who have a particular interest in the health and welfare of the horse, and equine dental technicians. If the information presented in this text benefits veterinarians, it will ultimately benefit their patients.

The number of illustrations found in the text has been greatly expanded from the number found in previous editions. The number of chapters has been expanded from 17 to 23 to reflect the expansion of knowledge in this field. References following each chapter can be used as a source for more in-depth study of topics covered within the chapters. The DVD provides visual as well as vocal demonstration of techniques of equine dental examination and prophylactic treatment.

The text represents the state-of-the-art of equine dentistry but it continues to be a work in progress for equine veterinarians. May the current enthusiasm of our profession continue to advance this specialty for the good of the horse.

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Equine dental evolution: perspective from the fossil record

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Introduction

It is generally believed that horses are native to the Old World and were first brought to North America by the Spanish explorers during the 16th century. While this is correct for historical times, the prehistoric fossil record of horses and their extinct relatives indicates that the Equidae underwent the majority of its evolutionary history in North America from about 55 million years ago (early Eocene) until this family became extinct about 10 000 years ago at the end of the last Ice Age (Pleistocene). The fossil record of horses in North America is a classic and compelling example of long-term (i.e., macro-) evolution.^{1,2} Fossil horses were exceedingly widespread and abundant in North America. Their teeth are highly durable and readily fossilize, and therefore figure prominently in our understanding of the evolutionary history of this group. This chapter will review what is known about fossil horse teeth and related morphological adaptations from the rich time sequence in North America to provide the framework within which teeth of modern *Equus* can be understood.

Equid interrelationships and phylogeny

Extant equids (horses, zebras, and asses) and fossil horses are classified in the family Equidae as part of the Order Perissodactyla, or 'odd-toed ungulates'. Other perissodactyl families include tapirs (Tapiridae), rhinoceroses (Rhinocerotidae), and several extinct families. So far as is known, all perissodactyls are united by a suite of unique characters including a concave, saddle-shaped navicular (central tarsal) facet on the astragalus (talus³), axis of symmetry through the central metapodial (III), hind-gut fermentation, and particular cheek tooth cusp morphology.² Likewise, so far as is known, all perissodactyls living and extinct have been herbivores. With the exception of the extinct clawed chalicotheres, all perissodactyls have a foot terminating with an ungual phalanx that is either padded or hooved.

The 7–10 (i.e., depending upon classification) extant equine species can all be conservatively classified within the single modern genus *Equus*.⁴ In contrast to this single genus, about 32 extinct genera and more than 150 species of fossil horses are recognized over the past 55 million years,^{2,5} and these also represent a far greater diversity of morphology and

adaptations than is seen in modern *Equus*. Fossil horses are first known 55 million years ago during the early Eocene throughout the northern continents (Fig. 1.1).⁶ These are represented by *Hyracotherium* (or 'eohippus', the dawn horse) and a solely Old World group, the palaeotheres (family Palaeotheriidae).⁵ Horses persisted in North America after the Eocene, but this family and the horse-like palaeotheres became extinct in the Old World by the early Oligocene, 29 million years ago. During the Oligocene and later times, the major evolutionary diversification of horses occurred in North America. Ancient dispersal events resulted in three-toed (tridactyl) horses immigrating into the Old World during the Miocene 23 million years ago (*Anchitherium*), 15 million years ago (*Sinohippus*), and after 12 million years ago (hipparions; Fig. 1.1). Extinct species of one-toed (monodactyl) *Equus*, which first originated in North America 4.5 million years ago during the Pliocene, subsequently dispersed into the Old World across the Bering Land Bridge 3.5 million years ago.⁷ During the Pleistocene after about 2 million years ago, *Equus* species also dispersed into South America after the formation of the Isthmus of Panama. The genus *Equus* subsequently became extinct 10 000 years ago throughout the New World at the end of the last Ice Age (Pleistocene).

Fossil horse dental adaptations

The earliest equid, *Hyracotherium*, is characterized by the primitive placental mammalian dental formula of three incisors, one canine, four premolars, and three molars (3 : 1 : 4 : 3), both upper and lower. The canine is large and sexually dimorphic.⁸ The premolars are primitive in structure, and roughly triangular in shape, whereas the molars are relatively square and have a greater surface area for trituration. During the Eocene and into the Oligocene, fossil horses in North America are characterized by progressive 'molarization' of the premolars (Fig. 1.2), resulting in a functional dental battery consisting of six principal teeth (P2/p2 through M3/m3) for mastication of foodstuffs. The cheek teeth of *Hyracotherium* and other early horses are short-crowned (brachydont). The preorbital cheek region is relatively unexpanded and the mandible is shallow (Fig. 1.3). Studies of dental structure and wear patterns suggest that these early horses were browsers, probably feeding on soft leafy vegetation and

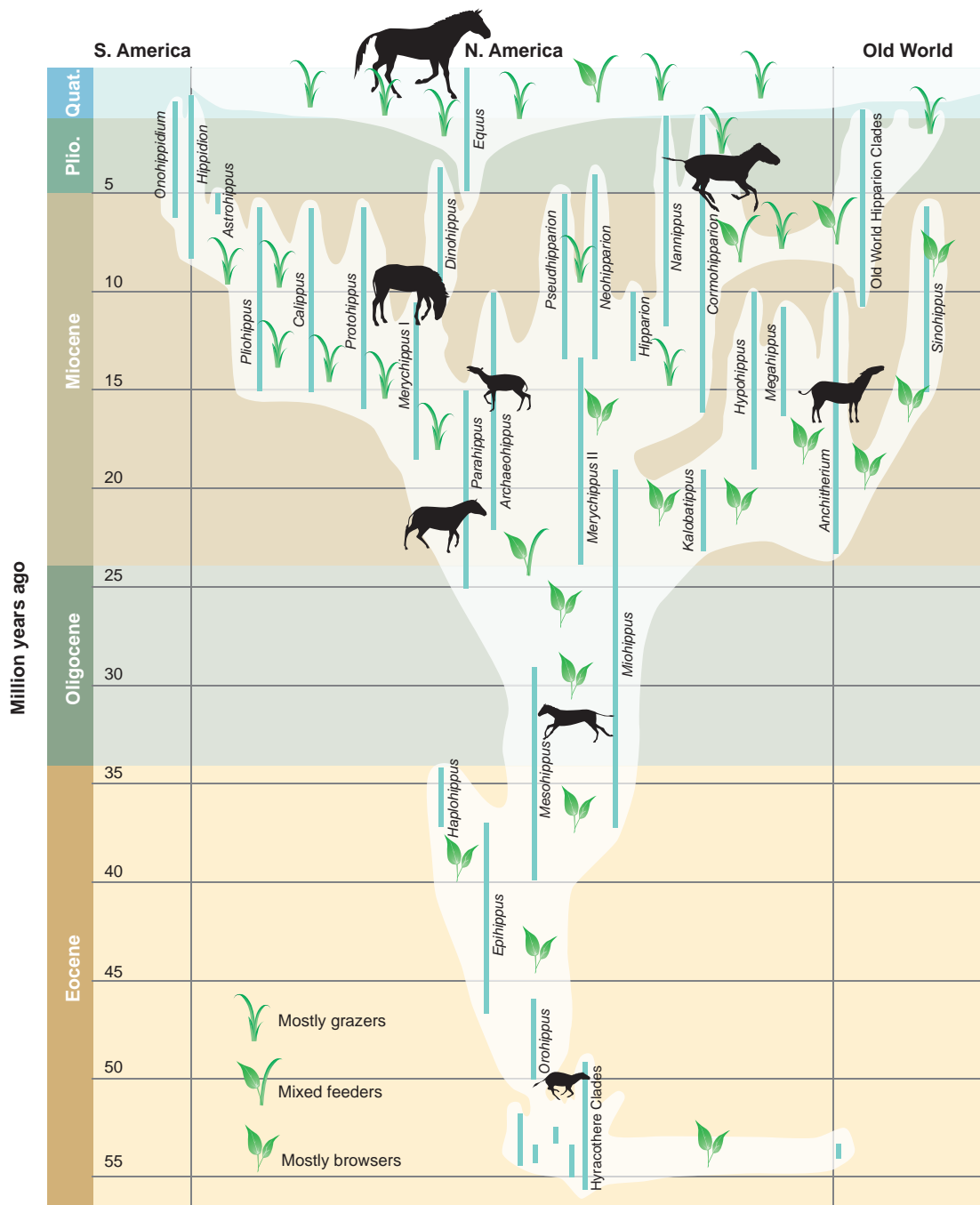


Fig. 1.1 Phylogeny, geographic distribution, diet, and body sizes of the Equidae over the past 55 million years. (From ref.⁶ and reproduced with permission of the American Association for the Advancement of Science.)

groundcover (e.g., including perhaps ferns) in ancient woodlands.⁸ This overall dental bauplan and inferred diet continued through the first half of equid evolution from 55 to 20 million years ago. (It also should be noted that grasslands had not yet evolved as principal biome types in North America.⁹)

The major morphological evolution of the equid skull and dentition occurred during the middle Miocene, between 20 and 15 million years ago.^{10–12} This evolution resulted in a morphology adapted for grazing, including a relatively longer cheek tooth row and deeper skull and jaws

accommodating high-crowned (hypsodont) teeth. Miocene and later horses with hypsodont teeth are principally interpreted to have been grazers, although there are exceptions to this rule. Hypsodont teeth are well adapted to increased wear resulting from eating abrasive grasses (in contrast to soft browse), as well as ingesting contaminant grit from plants growing close to the soil substrate. Evidence from the fossil plant record indicates that grasslands became a dominant biome in North America during the middle Cenozoic⁹ and horses soon thereafter exploited this newly available food resource as they invaded the 'grazing adaptive zone,'¹

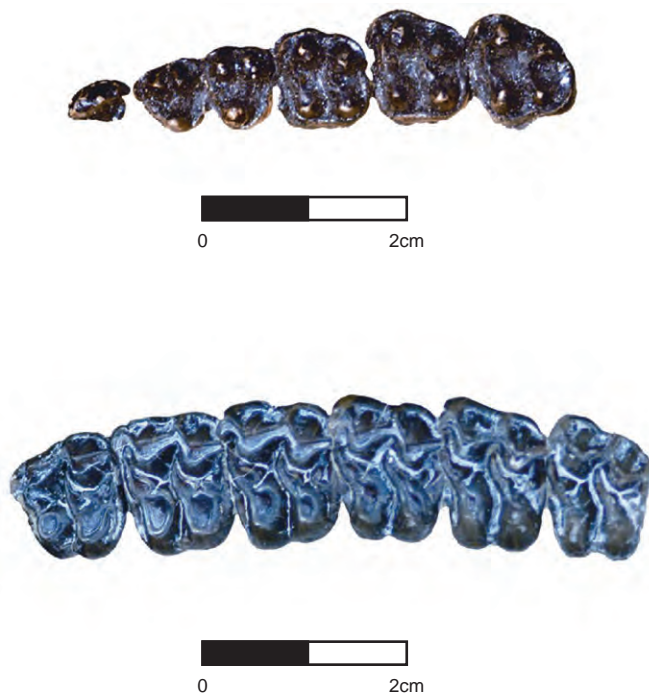


Fig. 1.2 Upper cheek tooth dentitions (excluding anterior-most P1) of Eocene *Hyracotherium* (top) compared with Oligocene *Mesohippus* (bottom). Note that relative to the triangular-shaped premolars (P2–P4; i.e., left three teeth in row) in *Hyracotherium*, those of *Mesohippus* are more square, or 'molarized.'

i.e., this is when they became grazers (Fig. 1.4).^{13,14} The maximum diversity of horses occurred during the middle Miocene when some dozen genera coexisted at some North American fossil localities.

The direct correlation between high-crowned teeth and grazing in horses is not absolute.¹⁵ Recent studies of the carbon content preserved in fossil hypsodont horse teeth indicate that some coexisting equid species secondarily acquired partial browsing diets.¹⁶ The extant genus *Equus* is first known 4.5 million years ago during the Pliocene from North America. It has a hypsodont dental battery and elongated and deepened skull and jaws, all of which are characters adapted for grazing (Fig. 1.3). Similar studies of the carbon content in extinct *Equus* teeth indicate that these horses were primarily grazers. However, depending upon available food resources and competing species, extinct *Equus* sometimes was a mixed feeder, incorporating some browse into its diet.

Trends in dental evolution

Number of teeth

Primitive equids from the Eocene have a dental formula of 3 I/i, 1 C/c, 4 P/p, and 3 M/m. The cheek teeth, consisting of the premolars and molars, represent the functional dental battery for post-cropping mastication. During equid evolution the rostral-most cheek teeth, P1/p1, were either reduced to small, relatively functionless teeth, or lost completely. In *Equus* the P1, or wolf tooth, is rudimentary, or often absent. The corresponding p1 is characteristically

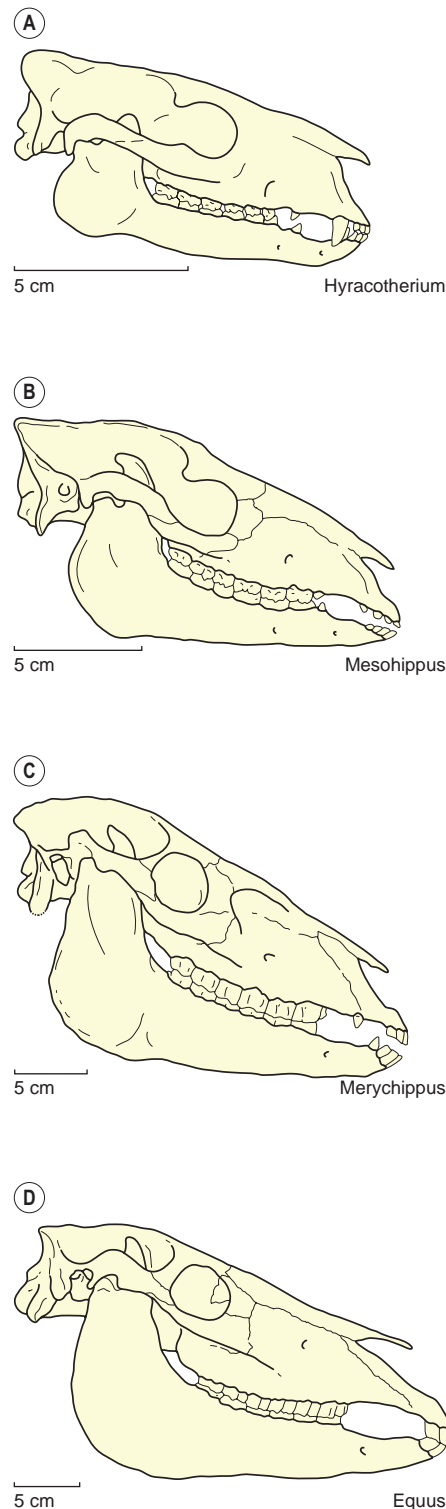


Fig. 1.3 Changes in the cranial proportions of the family Equidae as represented in Eocene *Hyracotherium* (top), Oligocene *Mesohippus*, Miocene *Merychippus*, and Pliocene – modern *Equus* (bottom).^{10,11} (From ref.² and reproduced with permission of Cambridge University Press.)

absent.^{3,17} Like most other mammalian families in which there is little evolutionary variation in the dental formula, other than the variable presence of the first premolar, equids are relatively constant in the dental formula throughout their phylogeny.



Fig. 1.4 Reconstruction of a Miocene savanna grassland in North America showing a diversity of horse species, as they might have existed in a local community. (From ref.¹³ and reproduced with permission of the American Museum of Natural History.)



Fig. 1.5 Left partial adult mandible of the three-toed hypsodont horse *Cormohipparion plicata* from the late Miocene (≈ 9 million years old) of Florida showing the deposition of cement (above arrow) on the erupted portion of p2 (above alveolus) and p3–p4 (bone removed).

Histology

The teeth of primitive horses demonstrate three primary dental tissues: pulp, dentin, and enamel. The composition of each of these dental tissues is developmentally very conservative, i.e., there is little variation in mammals, including equids.¹⁸ Composed of collagen, connective tissue, and reticulin fibers, pulp is the relatively soft tissue located in the center of the tooth,¹⁹ but is not normally exposed on the occlusal surface unless the tooth is heavily worn. Enamel and dentin are characterized by an inorganic component consisting of the mineral hydroxyapatite (the primary constituent of vertebrate bone). Enamel is more than 95 %

hydroxyapatite, whereas dentin is about 75 % mineral, the remaining portion consisting of organic compounds, mostly collagen.²⁰ Minor chemical variations in fossil teeth result primarily from changes in diet, difference in climate, and the source elements available in the animals' environments. Considerable infolding of the enamel occurs in later, hypsodont horses, resulting in a more durable tooth surface. Cementum, the external dental tissue in extant horses, first appeared during the Miocene in advanced species of *Parahippus*, and thereafter it was characteristically developed in hypsodont species (Fig. 1.5). Cementum is seen in numerous herbivorous mammalian groups and functions to provide an additional occlusal surface for mastication of abrasive foodstuffs, i.e., principally grasses.²¹

Dental ontogeny and wear

Most ungulates, including horses, are characterized by determinant dental growth of two sets of premolars and one molar series. Likewise, the individual teeth are characterized by growth that is completed during the lifetime of the individual when crown enamel mineralization ends and the roots form. Despite the fact that some mammals, e.g., elephants and manatees, have supernumerary tooth sets, and other mammals, e.g., rodents and lagomorphs, possess teeth that are ever-growing, the dental ontogeny in the family Equidae is conservative. A fixed set of premolars and molars and determinant tooth mineralization during an individual's lifetime is pervasive in fossil horses and *Equus*, with one notable exception. One species of tiny three-toed horse, *Pseudhipparion simpsoni*, from the 4.5-million-year-old Pliocene of Florida, had teeth that were partially ever-growing,²² thus providing an effective dental battery for feeding on abrasive foodstuffs and potentially increasing individual longevity.

Like modern horses, individuals of fossil equid species can be aged by the relative wear on teeth as represented in large quarry samples presumed to be ancient populations. It also can be determined if breeding was synchronized, thus implying a relatively seasonal ancient environment, or occurred year-round as in more equable climates. In seasonal climates, tooth wear was discontinuous within the population because births occurred in annual cohorts, i.e., a group of individuals that all started to wear their teeth about the same time (Fig. 1.6). In contrast, species that lived in equable climates will demonstrate continuous wear because individuals were born at different times during the year.

When horses are aged from fossil sites by the amount of wear on their teeth, we can see that potential individual longevity has evolved since the Eocene (Fig. 1.7). Eocene and Oligocene horses from 55 to 30 million years ago indicate a maximum potential longevity of 4–5 years per individual based on tooth wear and population analysis of *Hyracotherium* and *Mesohippus*. Beginning about 20 million years ago during the Miocene, cohort analyses indicate an increase in potential longevity from 5–15 years depending upon taxon,² and thereafter up to 20–25 years per individual during the Pliocene and Pleistocene, as also has been reported for wild populations of *Equus*.⁴ As longevity is generally correlated with adult body size in modern mammals,²³ it is not surprising that longevity increased in fossil horses over the past 20 million years because this also was the time of dramatic increases in body size.²⁴

Sexual dimorphism

Relative to certain modern mammalian species in which the males can be as much as 30–40% larger than females within a population,⁴ the degree and expression of sexual dimorphism as represented in skeletal hard parts is relatively minor in living *Equus*. While male equids are generally larger²³ and have relatively more robust canines, these sexually dimorphic characteristics are much less distinctive than in fossil equids.

A quarry sample of 24 individuals of *Hyracotherium tapirinum* from a 53-million-year-old (early Eocene) locality from



Fig. 1.6 Progressive dental wear on the lower cheek teeth of the three-toed horse *Parahippus leonensis* from the 18-million-year-old Thomas Farm locality, Miocene of Florida. The different wear stages shown are interpreted to represent individuals that died at different ages within the same population. The top dentition (A) probably represents an individual about 2 years old, whereas that at the bottom (D) was probably about 9–10 years old when it died. The occlusal enamel pattern is indicated in black. Pulp is exposed in the center of each tooth in Wear-class 9. (Modified from ref.² and reproduced with permission of Cambridge University Press.)

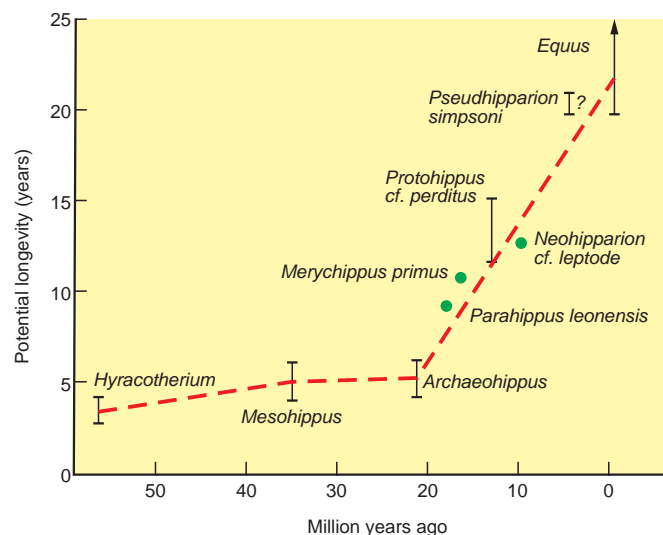


Fig. 1.7 Evolution of individual potential longevity in selected species of fossil Equidae based on analysis of the population dynamics of well-preserved quarry samples. (From ref.² and reproduced with permission of Cambridge University Press.)

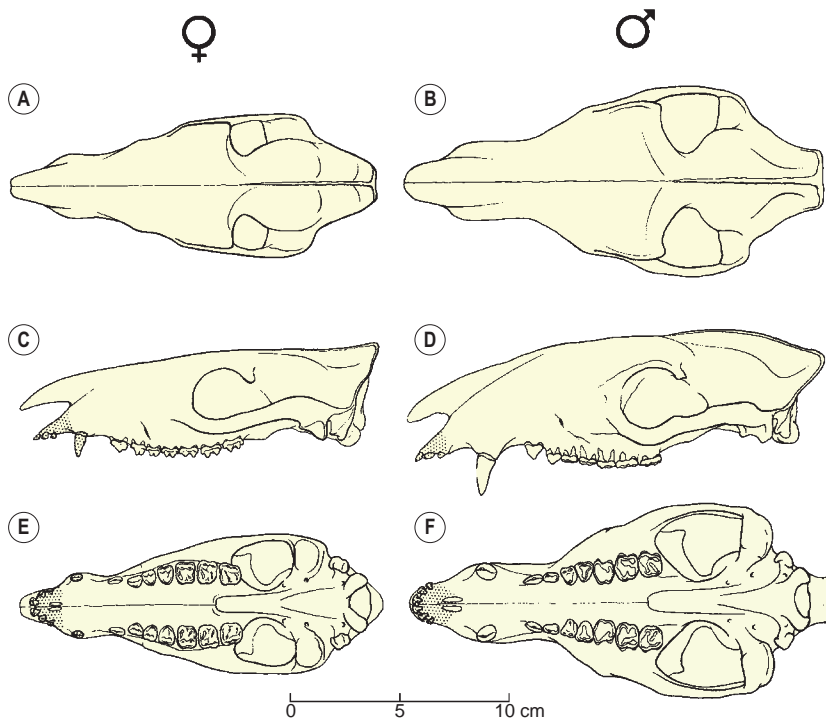


Fig. 1.8 Dorsal, left lateral, and ventral views of female (left: A, C, E) and male (right: B, D, F) crania of *Hyracotherium tapirinum* from the 53-million-year-old Huerfano Quarry, Eocene of Colorado. These are from the same locality and therefore interpreted to represent individuals within the same ancient population. Note the larger cranium and canine in the male. Shading indicates reconstruction. (Modified from ref.⁸ and reproduced with permission of the Paleontological Society.)

Colorado gives insight into the sexual dimorphism in cranial and tooth size in this early horse.⁸ The males are on average 15% larger than females, and have markedly robust canines relative to females (Fig. 1.8). Thereafter, during the Eocene through early Miocene, size and canine dimorphism are characteristic of more primitive species for which there are sufficient samples for statistical discrimination. With the evolution of open-country grazing forms during the Miocene, cheek teeth are essentially monomorphic,²⁵ but sexual discrimination can be seen in the relative canine size (Fig. 1.9). Likewise, in an extraordinary quarry accumulation interpreted to represent an ancient population of *Equus* (*E. simplicidens*), the species close to the origin of the modern genus, from 3.5-million-year-old Pliocene sediments of Idaho,²⁶ males and females can be distinguished based on relative canine size.

Cranial adaptations

The 55-million-year evolutionary history of the family Equidae is characterized by profound changes in cranial morphology. Primitively, *Hyracotherium* had a skull in which the orbit was centrally located, a postcanine diastema, and a relatively shallow mandible that accommodated short-crowned teeth (Fig. 1.8). In contrast, *Equus* has a preorbital region that is much longer than the postorbital region, a relatively more elongated diastema, and the mandible, which accommodates high-crowned teeth, is very deep. These trends all relate to the fundamental change in diet that occurred from the morphology seen in *Hyracotherium* to that of *Equus*. This evolution, however, was not gradual, and a major morphological reorganization occurred in equid skulls during the Miocene related to the adaptation to grazing.^{10,11}

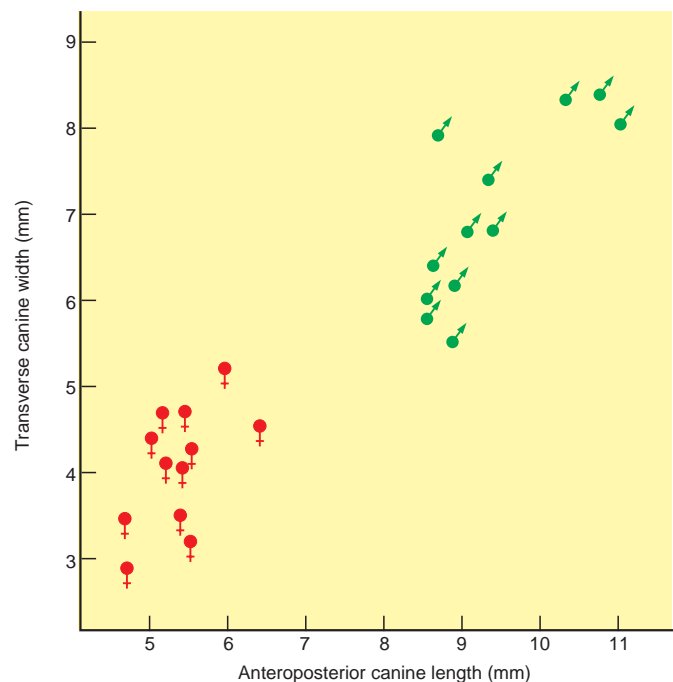


Fig. 1.9 Bivariate plot of canine length versus width in a late Miocene quarry sample of the three-toed horse *Hipparion tehonense* from MacAdams Quarry, Texas. The distinctly bimodal populations represent individuals interpreted to represent females (lower left) and males (upper right). (Modified from ref.²⁷ and reproduced with permission of the American Museum of Natural History.)

Although not directly related to diet and feeding adaptations, fossil horses show a fundamental evolution in the cheek region over the past 20 million years during the middle Cenozoic. Primitively, *Hyracotherium* has a smooth preorbital cheek region (junction of nasal, maxillary, and



Fig. 1.10 Adult skull and mandible (left side) of 18-million-year-old, three-toed, short-crowned *Archaeohippus blackbergi* from the Miocene of Thomas Farm, Florida, showing dorsal preorbital fossa (below finger). The orbit is to the right of the fossa.

lacrimal bones), but during the Miocene there was an adaptive radiation resulting in an elaboration of a pit, or multiple pits, in the facial region. These are collectively termed preorbital fossae, of which the dorsal preorbital fossa is most widespread (Fig. 1.10). Preorbital fossae are absent in living *Equus*, so the function of this structure cannot be based on a modern closely related analog, and has, therefore, engendered much discussion in the literature. One theory suggests that preorbital fossae housed an organ complex that could have been used for vocalization. The time of maximum morphological diversity of facial fossae is seen at the time of maximum equid diversity during the Miocene. During the Pliocene and Pleistocene, when equid diversity declined, facial fossae became reduced and were ultimately lost in *Equus*.²

Summary: modern *Equus*

The cranial and dental adaptations of modern *Equus*, in particular the elongated preorbital region, high-crowned

molarized cheek teeth, and deep mandible, represent an integrated character complex related to feeding on abrasive foodstuffs. These morphological adaptations are first seen 20 million years ago during the Miocene when equids exploited the grazing niche during the expansion of grasslands. The 55-million-year fossil record, particularly the ubiquitous and abundant horse teeth, provides fundamental evidence for macroevolution within the family Equidae in North America.

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References

1. Simpson GG. Horses: the study of the horse family in the modern world and through sixty million years of history. Oxford University Press, Oxford, 1951
2. MacFadden BJ. Fossil horses: systematics, paleobiology, and evolution of the family Equidae. Cambridge University Press, New York, 1992
3. Getty R. Sisson and Grossman's The anatomy of domesticated animals. WB Saunders, Philadelphia, 1975
4. Nowak RM. Walker's Mammals of the world, 5.1. Online. Johns Hopkins, Baltimore, 1997
5. McKenna MC, Bell SK. Classification of mammals above the species level. Columbia, New York, 1997
6. MacFadden BJ. Fossil horses—Evidence for evolution. *Science* 2005; 307: 1728–1730
7. Lindsay EH, Opdyke ND, Johnson ND. Pliocene dispersal of the horse *Equus* and late Cenozoic mammalian dispersal events. *Nature*, 1980; 287: 135–138
8. Gingerich PD. Variation, sexual dimorphism, and social structure in the early Eocene horse *Hyracotherium* (Mammalia, Perissodactyla). *Paleobiology* 1981; 7: 443–455
9. Jacobs BF, Kingston JD, Jacobs LL. The origin of grass-dominated ecosystems. *Annals Missouri Botanical Garden* 1999; 86: 590–643
10. Radinsky LB. Allometry and reorganization in horse skull proportions. *Science* 1983; 221: 1189–1191
11. Radinsky LB. Ontogeny and phylogeny in horse skull evolution. *Evolution*, 1984; 38: 1–15
12. MacFadden BJ, Hulbert RC, Jr. Explosive speciation at the base of the adaptive radiation of Miocene grazing horses. *Nature*, 1988; 336: 466–468
13. MacFadden BJ. The heyday of horses. *Natural History* 1994; 103(4): 63–65
14. MacFadden BJ. Origin and evolution of the grazing guild in New World terrestrial mammals. *Trends in Ecology and Evolution* 1997; 12: 182–187

15. Janis CM. An estimation of tooth volume and hypsodonty indices in ungulate mammals, and the correlation of these factors with dietary preference. In: Russell DE, Santoro JP, Sigogneau-Russell D, eds. *Teeth revisited: Proceedings of the VIIth International Symposium on Dental Morphology*, Paris 1986. Mémoires Musée National Histoire Naturelle, Paris (série C). 1988; 53: 367–387
16. MacFadden BJ, Solounias N, Cerling TE. Ancient diets, ecology, and extinction of 5-million-year-old horses from Florida. *Science* 1999; 283: 824–827
17. Sach WO, Habel RE. Rooney's Guide to the dissection of the horse. Veterinary Textbooks, Ithaca, 1976
18. Janis CM, Fortelius M. On the means whereby mammals achieve increased functional durability of their dentitions, with special reference to limiting factors. *Biological Reviews* 1988; 63: 197–230
19. Dixon PM. Dental anatomy. In: Baker GJ, Easley J, eds. *Equine dentistry*. WB Saunders, Philadelphia, 1999, pp 3–28
20. Carlson S. Chapter 21. Vertebrate dental structures. In: Carter JS, ed. *Skeletal biomineralization: patterns, processes and evolutionary trends*. Vol 1. Van Nostrand Reinhold, New York, 1990, pp 531–556
21. White TE. The endocrine glands and evolution, no. 3: os cementum, hypsodonty, and diet. *Contributions from the Museum of Paleontology*, University of Michigan 1959; 13: 211–265
22. Webb SD, Hulbert RC, Jr. Systematics and evolution of *Pseudhipparion* (Mammalia, Equidae) from the late Neogene of the Gulf Coastal Plain and the Great Plains. In: *Vertebrates, phylogeny, and philosophy*, eds. KM Flanagan and JA Lillegraven, *Contributions to Geology*, University of Wyoming, Special Paper 3, 1986, pp 237–272
23. Eisenberg JF. The mammalian radiations: an analysis of trends in evolution, adaptation, and behavior. University of Chicago Press, Chicago, 1981
24. MacFadden BJ. Fossil horses from 'Eohippus' (*Hyracotherium*) to *Equus*: scaling, Cope's Law, and the evolution of body size. *Paleobiology* 1987; 12: 355–369
25. MacFadden BJ. Dental character variation in paleopopulations and morphospecies of fossil horses and extant analogues. In: Prothero DR, Schoch RM, eds. *The evolution of perissodactyls*. Clarendon Press, Oxford, 1989, pp 128–141
26. Gazin CL. A study of the fossil horse remains from the Upper Pliocene of Idaho. *Proceedings US National Museum* 1936; 83: 281–319
27. MacFadden BJ. Systematics and phylogeny of *Hipparion*, *Neohipparion*, *Nannippus*, and *Cormohipparion* (Mammalia, Equidae) from the Miocene and Pliocene of the New World. *Bulletin of the American Museum of Natural History* 1984; 179: 1–196

The history of equine dentistry

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Introduction

Diseases of teeth; this is a subject which I have little to offer.

William Percivall, 1824¹

Of the diseases of the teeth in the horse we know little.

William Youatt, 1831²

The diseases of the teeth attracting attention are but few.

William Dick, 1862³

These quotes from three prominent 19th century European veterinarians and scholars are accurate but ironic introductions to the history of equine dentistry. Accurate, because only recently has the equine veterinary profession taken steps to embrace dentistry as a legitimate medical practice best served by the licensed and well-trained practitioner. Ironic, because although significant advancements have been made associated with equine dentistry, similar quotes are heard from today's graduating veterinary students and seasoned practitioners. In many cases these concerns are justified since veterinary schools still do not spend a great deal of time teaching equine dental procedures. However, veterinary students and equine practitioners spend hundreds of hours learning the anatomical, biological, physiological, histological, medical, and surgical information necessary to practice sound equine dentistry. Philosopher and poet Georges Santayana stated, 'Those who do not study history are doomed to repeat it.' Perhaps by turning to the history of equine dentistry, we may benefit from its ancient roots and devote its future to development, not repetition of failures.

Expressions from historical folklore such as, 'long in the tooth' or 'don't look a gift horse in the mouth,' reference horses' teeth. Much of this history is buried in hand-made materials such as manuscripts, folios, tablets, and paintings utilizing ancient characters, or languages. Before the invention of printing, these documents were transferred throughout the ages by scribes, leaving much room for error, superstition, and quackery. Most of this history of the horse is located in European libraries and was not readily available

until recently with the development of the web and other internet services.^{4,5} Through careful scrutiny of available texts and other sources, the intriguing history of equine dentistry may be pieced together.

Ancient roots

Hyracotherium was a prehistoric rabbit-sized creature that was the precursor to our modern horse, *Equus caballus*. As evolution progressed, this animal went from consuming leaves and having brachydont (simple low-crowned) teeth to chewing on grass and adjusting with hypsodont (high-crowned) teeth. This, along with enamel folding and the coronal cement, created a grinding surface appropriate for the spicules of silica within the grass as discussed in detail in Chapter 1.⁶

As humans began to domesticate animals, responsibility for their medical care and well-being fell into the hands of caregivers. Written records from 2200 BCE within the *Codex of Hammurabi* in Babylon show the establishment of a code of ethics allowing for medical practice on both humans and animals. Other instructions included fees allowed to be charged for medical services as well as those which barbers (ancient beard trimmers and medicine men) charged for pulling teeth.⁴ The *Kahane* papyrus from 1850 BCE Egypt makes no reference to horses. However, Egyptian carvings and paintings dated from 2000 BCE portray individuals performing what appear to be oral examinations on various poultry and livestock. None appear to depict any equine species simply due to the fact that the ancient Egyptians did not extensively use horses or donkeys. However, the *Codex of Hammurabi* does provide proof that donkeys were used in Asia Minor and the Orient during this time period.⁴

The domestication, riding, and breeding of horses can be traced back prior to 1000 BCE in Asia. Archeological and paleontological evidence indicated that the horse was domesticated about 5000 years ago, substantially later than other farm animals. By that time (approximately 3000 BCE) the dog had been our companion for 9000 years and we had herded goats, sheep, and cattle for upwards of 5000 years. The horse came late but lost no time in transforming our lives. Sequentially, as horse selling became more popular, the ancient Chinese practice of 'aging' by examining teeth

became an invaluable tool.⁷ As the art of riding and selling horses spread from Asia to Europe it became engrained within the Greek and Roman societies. From 430–354 BCE Xenophon, a student of Socrates, collected his experiences on the art of riding in the document, *Peri hippikes* (On horsemanship). This text makes reference to the art of riding being restricted to the upper class who kept ‘heads of stables’, ‘equeries’, and ‘masters of the horse’, to care for their horses. It also references the use of a ‘machina’, Latin for mouth-gag, used to administer medicinal drenches or to aid with the clearing of esophageal obstructions while utilizing a stick.⁸

Several other important documents were also created throughout this period as the use of horses in transport, agriculture, and military work became increasingly more important. *The Veterinary Art, Inspection of Horses* by Simon of Athens and the *History of Animals* by Aristotle were produced in 430 BCE and 333 BCE, respectively. Both manuscripts contain information regarding the aging of horses by examination of their teeth. Simon’s text discusses eruption patterns and Aristotle’s includes information on periodontal disease. It is suspected that additional collections of valuable equine text were lost during the fire in Alexandria in 391 AD that destroyed the largest library of the ancient world with at least 700 000 volumes consumed.⁴

As the Roman Empire flourished, a few significant medical documents were created with additions of personal observations and local superstitions. In 400 AD, Chiron, a Roman writer often confused with the Centurion god and son of Apollo, created manuscripts including Book VI that contained information on tumors of the jaw, diseases of the teeth, and management of jaw fractures. In addition, Book VIII contained a description of dentition. Another major Roman contributor to early veterinary medicine was Vegetius who recorded *The Veterinary Art* between 450 and 500 AD. This document included not only works on aging, but also a description of the ‘pain of sockets of the teeth,’ the only reference to periodontal disease from that time. The treatment of choice for this affliction was to rub vinegar and chalk to the outside of the jawbone. Much of Vegetius’ work relied upon the previous writings of Apsyrus, the senior veterinarian of Constantine the Great’s army in 333 AD. However, Vegetius’ text is still considered a cornerstone of ancient equine literature and was translated into English and reprinted in 1528, making it one of the first veterinary texts to be printed. Apsyrus’ work may also be found in the *Hippiatrica*, a manuscript compiled by order of Emperor Constantine VII. This text also contained a section on dentition by Hierocles from 350–400 AD.^{4,9}

As the Dark Ages enveloped Europe, learning shifted east as Arabic equine education benefited from the magic within *Hippiatrica* and the widespread military use of horses. Contributors included the author Ibn al Awam from Seville, Spain, whose manuscript (1100 AD) contained a section on dentition. Around 1200 AD Abou Bekr created the *Nacari* which displayed a section on dentition, operations, a sketch of early hand-held mouth gags used for the extraction of teeth, and the cutting/breaking of long molars. His work also included recommendations for using files and floats for trimming unequal teeth. Hassan Ibn al Ahnaf’s manuscript in 1209 AD contained a drawing of a tooth extraction using forceps.^{8,9}



Fig. 2.1 A farrier's shop (1648) by Paulus Potter, a famous Flemish animal painter (1625–1654). Potter shows a farrier (horse doctor) wearing a red jacket and leather apron, examining the mouth and teeth of a restrained horse.

Stablemasters

The horse’s role in work and transportation gained importance throughout Europe during the medieval era, but medical advancements in Europe were few and far between. As the value of horses increased with upper-class showmanship, the importance of having a well-shod animal fell into the hands of farriers (Fig. 2.1). Consequently, a revival in the advancement of veterinary medicine began in the late 13th century. From 1212–1250 AD Emperor Friedrich II of Hohenstaufen held court in Naples, Italy, and commissioned Giordano Rosso from Calabria and Master Albrant, a farrier of German descent, to manage all of his equine care. Both men detailed their experiences including ancient Arabic prescriptions in various manuscripts which Rosso, a noble man by birth, published in Latin. Albrant, a less formally educated man, published his experiences, including aging (utilizing previous texts) and the use of herbal medicines to heal oral mucosal wounds. Published in German, the more common people were able to read and understand Albrant’s text but much of his knowledge was passed on by word of mouth, leading to large discrepancies and regional superstitions (Fig. 2.2).

In 1250 AD, with the Renaissance occurring in Europe, Johannes Ruffus, the chief veterinarian to Frederick II of Sicily, created *Equine Medicine*. This detailed text included a description on cutting a horse’s lip to accommodate the bit, dental extraction techniques, as well as reference to false incisor alterations created by horse owners to make horses for sale appear younger. ‘Bishoping,’ named after a scoundrel who utilized the practice, became popular in England throughout the 16th century and beyond, as horse sellers increased profits by making their horses appear younger or older, whichever proved more valuable and to their benefit. A reference to this behavior is found as late as in Jacques L. de Solleysel’s 1664 text, *Le parfait mareschal*. Solleysel ‘complained bitterly,’ describing a German’s practice of changing horses’ teeth appearance as inappropriate.⁸



Fig. 2.2 Farriers and horsemen inflicted many painful and barbaric treatments on their horses during the Middle Ages and beyond. An 18th century complaint against the existing order. (Reproduced from Bracken 1737 *Farriery improved*.)

During the crusades and the Moors' invasion of Spain, European and Arabian cultures crossed. Much of the Arabian knowledge previously compiled influenced Europe, and more specifically Spain. Juan Alvarez Salmiellas translated some 96 chapters of ancient Arabian horse knowledge into Spanish which comprised the most complete manuscript of equine knowledge available at the time. Manuel Diaz, major domo of King Alphonso of Aragon, compiled his text *Libro de Albeiteria* of equine diseases utilizing Arabian influences. In 1492, Queen Isabella of Castilla in Spain defeated the Arabian conquerors in the Battle of Granada. Realizing the importance of horses in warfare, she devoted time and some of her treasure to the development of equine science. By 1500, laws had been established calling for albietares, or horse doctors, to be properly trained through apprenticeships.⁸ Despite advances in the field of equine dentistry, many discrepancies remained. In 1566, Blunderville stated that horses only have 16 teeth, due to the fact that only the 12 incisors and 4 canine teeth could be easily examined. It was evident from his work that he was unaware that horses have cheek teeth. Millennia earlier, Aristotle correctly placed the number of equine teeth at 44. Blunderville also addressed that horses with small mouths have the angles of their lips cut by an 'expert horse-leech' and cauterized to prevent healing over. As an additional means of making room for the ornate bits of the time, he recommended that the lower tushes (canine teeth) be extracted (Fig. 2.3).⁴

Barbary

Throughout the 16th, 17th and 18th centuries medical procedures were most commonly performed by owners, horse



Fig. 2.3 Large and brutal bits used by the Italians necessitated cutting the commissures of the lips and removing the lower tushes. The Turkish figure suggests an Eastern origin for these monstrosities, and perhaps symbolizes the burden borne by the hapless horse. (Feraro 1560 *Cure of horses*, reproduced from Smithcors 1957,¹⁰ p. 150, with permission from Veterinary Medicine Publishing Company.)

leeches, farriers, and quacks. Often, the barbaric treatments utilized were based on superstitions handed down from previous generations. In England the agriculture writer, John Fitzherbert, whose text *Boke of Husbandrie* (1523) provided expert advice, was an important influence on agriculture practices for several centuries. His work helped perpetuate a number of imaginary equine diseases, three affecting the mouth: 'lampas' or swelling of the palate, 'barbs', the papillated openings of the salivary ducts, and 'vives', which appears to be a non-pathological enlargement of the parotid salivary gland. Fitzherbert insisted the vives must be 'killed' before it can 'eat the roots of the ears'. 'Vives' had also been mentioned by Ruffus two centuries earlier.¹⁰ From the middle ages until the 19th century, wolf teeth were also blamed for various ailments including blindness and 'madness' with their removal apparently relieving the symptoms. While lacking proof, the chosen methods to remove wolf teeth with a carpenter's gouge, chisel and mallet or by filing them, appeared in the literature of this time period and beyond.

M. LaFoose in 1749 used a trephine to open the sinuses, as a means of treating nasal 'gleet' caused by glanders or sometimes dental disease.⁴ Reports of farriers using a chisel and hammer to remove focal dental overgrowths ('hooks') and sharp edges, tall teeth reduced with saws, and teeth extracted with a long fixed iron instrument called a 'key', without the aid of a speculum, often resulted in damage such as jaw fractures and even death. Designs of a scissor type instrument invented to cut the difficult distal hook on the last molar and various patterns of sliding chisels and screw-type molar cutters are found in textbooks published during this era.⁸ Most of these tools were still manufactured and sold into the 20th century (Fig. 2.4).

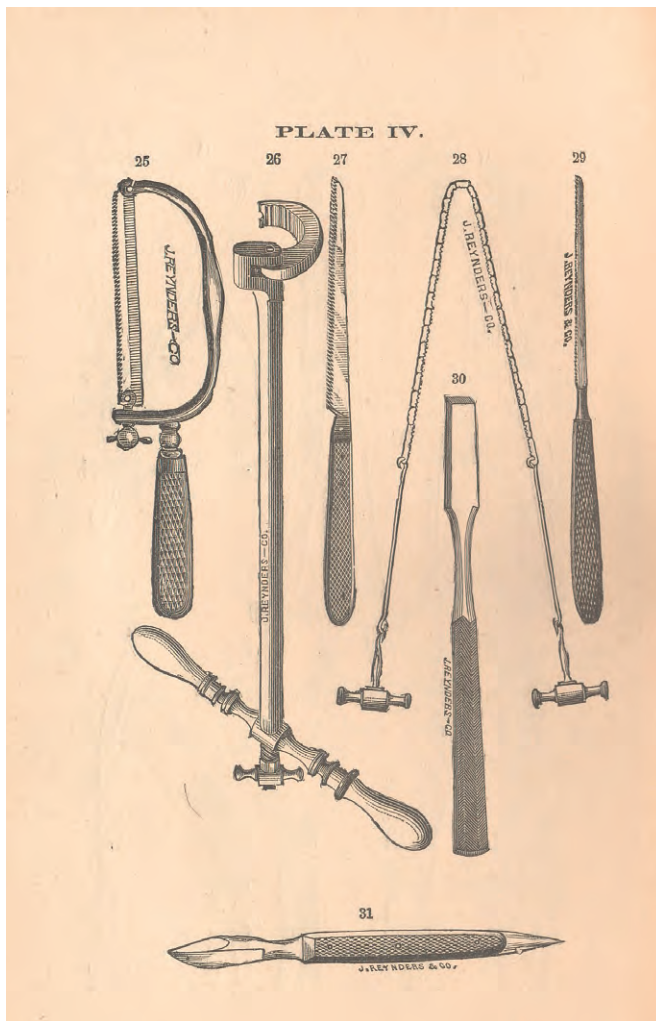


Fig. 2.4 Equine Dental Instruments, Plate IV, John Reynolds & Co, New York, from Clark (1893). Price list and descriptions: 25. Bow tooth saw with two blades ... \$6.00, 26. Tooth key with hooks of assorted sizes ... \$35.00, 27. Plain tooth saw ... \$1.50, 28. Chain tooth saw ... \$12.50, 29. Fine ferruled tooth saw ... \$1.75, 30. Narrow tooth chisel, length 6 inches ... \$1.25, 31. Hurlburt's gum knife and tooth pick ... \$2.00.

Another commonly performed, barbaric, and unscientific procedure involving the mouth of the horse was the treatment of 'lampas.' This 'defect' occurs as the palatal epithelium physiologically begins to bulge, resulting from erupting incisors in younger horses. Included in almost all farriery texts prior to the 1900s, the treatment of choice was to cauterize the region with a hot iron, allow the horse to rest a day or two, and repeat if necessary (Fig. 2.5).

Solleysel, as early as 1664, was the first to document this change in young horses as entirely normal and advised against the cauterization process and much debate ensued.⁴ This practice was still being performed when William Percivall wrote in 1823 that the treatment of the imaginary lampas by cautery be considered to be a 'stigma on our national character and a disgrace to veterinary science.'¹ Youatt in his 1846 publication states, 'a few slight incisions across the bars with a lancet or penknife will relieve the inflammation.'² Although addressing this 'affliction' Youatt found himself in a common predicament. The inflammation

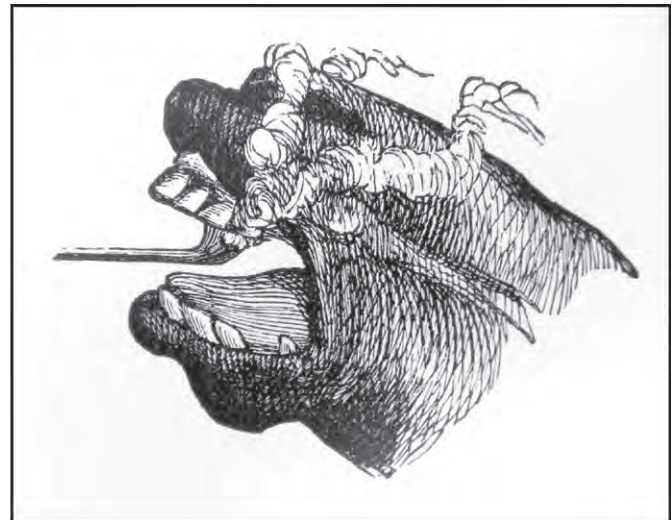


Fig. 2.5 Burning for lampas. A red hot iron was placed in the roof of the young horse's mouth to relieve the symptom of this imaginary disease. (Edward Mayhew, 1888 *The illustrated horse doctor*, p. 66.)

associated with this disease is often the result of a simple feed change. Stablemasters would move a young horse off pasture and into the stable, altering the diet with dry feed-stuff. Veterinarians found it more difficult to convince the stablemaster, the affliction was physiological, and found it easier to simply 'treat' the problem. Veterinarians still treat imaginary diseases today, regardless of scientific evidence, as client pressure still dictates many actions.

Although the majority of veterinary medical treatments were documented, a large percentage of them contained errors and misinterpretation due to mistakes in translation. Martin Boehme, a horse smith serving in the armies of Germany, Holland, and Hungary in 1618, was called to court by Johann Georg of Brandenburg to establish the first pre-university veterinary education and formalize a learning environment leading to organized academia. He was also attributed with publishing the first exact prints (woodcuts) of various equine dental instruments in his text, 'Ein nett Buch von bewehrter Ross Artzeneyen.'⁸

The Age of Enlightenment and the introduction of formal education

During the 18th century, scientific, rational, and evidence-based thought began to displace the previously held religion-centered philosophies. The Age of Enlightenment produced a wave of writers and thinkers with scientific backgrounds who used their ideas and authority to establish scientific societies and academies throughout Europe and North America. These societies became the backbone of the scientific profession during the time and ushered in significant advancements in biology, chemistry, and in the practice of medicine. Consequently, the advancement of science and medicine spilled over to the veterinary community. In 1762, the first veterinary school was established in Lyon, France, and the second followed quickly in 1766 in Alfort, France, near Paris. Disorders of the horse were the pre-eminent

subjects in all veterinary schools for almost the next two centuries. Although advancements in equine veterinary practice were being made through formal education, dentistry was not a priority of the curriculum. Farriers were still responsible for conducting the majority of veterinary treatments but were beginning to be considered as 'a carpenter compared to the architect: both having to do with the same thing, with only the architect understanding the underlying principles.'¹¹

As veterinary education began to flourish, so did the amount of technology and literature created by experts. Surgical techniques initially gained attention due to the mystery shrouding many medical ailments affiliated with then undiscovered bacterial and viral infections. In 1805, Professor Hayemann from the Hannover veterinary school described a procedure where the skin is incised crosswise under the apex of a diseased tooth, then flapped in order to chisel the bone away, thus exposing the root of the tooth. He then described using an iron punch to hammer it out. Jaw and tooth fractures were common consequences but this repulsion procedure is still in part used today. In 1835, Jean-Baptiste Girard, as director of the Veterinary School of Paris Maison Alfort, published the *Traité de l'age du cheval* for his son who was an anatomy professor at the same institution. Girard was the first to describe the inconsistent nature and shedding of the wolf teeth at 2.5 years when the deciduous first cheek tooth (Triadan 06) displaces it. He also made clear that the presence of canine teeth has nothing to do with sterility, another common misconception at the time.¹²

New surgical techniques such as the previously described cheek teeth extraction, created a demand for appropriate instrumentation and an opportunity for new companies. Arnold & Sons of England met this demand by making dental floats and other instruments in 1817. J.H. Friedrich Guenther and his son Karl W.A. Guenther, both also famous professors at the Hannover veterinary school, were influential in advancing the tools used for equine dentistry. In 1859, they published *Die Beurtheilungslehre des Pferdes* which included a 164 page chapter on teeth, a chapter on aging, descriptions of 36 innovative instruments used for dental surgery accommodating the different shapes and positions of all teeth, and a diagram of a mouth gag utilizing a screw spindle (Fig. 2.6).⁸

The origins of organized veterinary dentistry

The American Civil War and westward expansion of settlers cemented the popularity and utility of the horse in American culture during the mid to late 1800s. With formal veterinary education established throughout Europe, the youthful United States opened its first veterinary school in 1875. The majority of early American veterinary practitioners were migrant European veterinarians such as John Haslam, a 1799 or 1801 graduate of the Royal Veterinary College of London, who most likely practiced in Baltimore. The 7th United States Census reported 46 practicing veterinarians in 1850 but this number had increased to 392 by 1860. With the establishment of formal veterinary education, the United States Veterinary Medical Association published their first scientific journal, *The American Veterinary Review* in 1877. The title of this often referenced 'Review' was changed in



Fig. 2.6 French World War I military veterinarian working on a horse's teeth. The mouth is held open with a Gunther speculum.

October of 1915 to the *Journal of the American Veterinary Medical Association*, to accompany the association's new name, the American Veterinary Medical Association. The name change took place in 1898 in order to recognize veterinarians in both Canada and the United States.^{11,13}

The doorway for advancement in equine veterinary medicine and equine dentistry had been opened as scientific experimentation led the way for significant published advances in knowledge, improved instrumentation, and collections of data. Robert Jennings, a Philadelphia veterinarian, stated in 1865 that the 'horse was subject to caries' (tooth decay) and collected 350 well-defined specimens of caries in horses' teeth. He later published his findings in an article entitled *Diseases of the Horses Teeth*, which may be found in the Archives of Comparative Medicine of 1883.¹¹ Another important textbook, *Veterinary Dental Surgery*, published in 1889 by T.D. Hinebach, a Professor at Purdue University in Lafayette, Indiana, described dental anatomy, physiology, pathology, and therapy complete with illustrations. He illustrated the use of instruments by Sharp & Smith along with a mechanical drill borrowed from human dentists (Figs 2.7, 2.8). In the text he described techniques for filling in decayed incisors and molars.¹⁴ *The Exterior of the Horse*, penned originally by Goubaux and Barrier and later translated from French in 1892 by Simon J.J. Harger, contained over 900 pages including 360 figures of which 120 were of horses' teeth with detailed anatomical illustrations.¹¹

In the late 19th century major improvements in equine dental instrumentation began to appear in uniquely designed tools such as the 'Frick/Hauptner Universal Forceps' created by a professor of surgery in Hannover, Germany in 1889. His cheek teeth forceps contained two adjacent bars which rotated in two joints, thus closing the jaws in a parallel fashion allowing for proper application (Figs 2.9–2.11). Previous forceps had jaws that rotated around a riveted joint

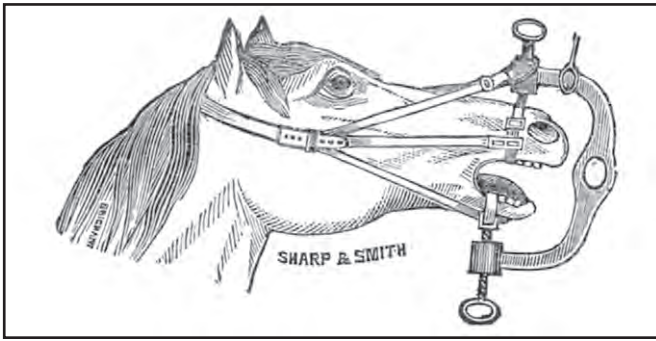


Fig. 2.7 Simons mouth speculum with a screw mechanism to aid in opening the mouth of the unsedated horse. The speculum put pressure on the bars of the mouth. Sharp and Smith manufacturers and importers of superior surgical veterinary instruments, Chicago. (Hinebauch, 1889, p. 235.)

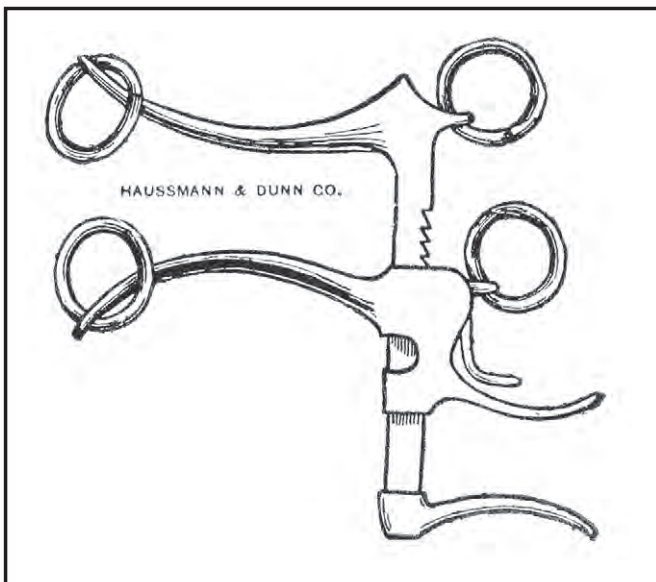


Fig. 2.8 A mouth gag that rests on the horse's bars. (Merillat 1905.)

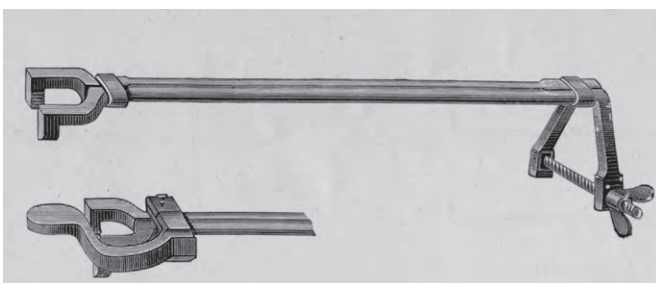


Fig. 2.9 Frick and Hauptner's 'Universal' forceps. The clamping head is shown with and without the fulcrum. (Regional Veterinary Surgery 1904, p. 49.)

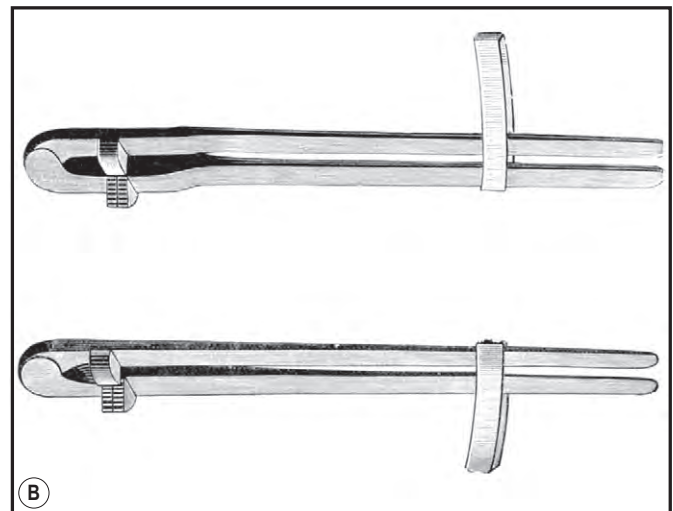
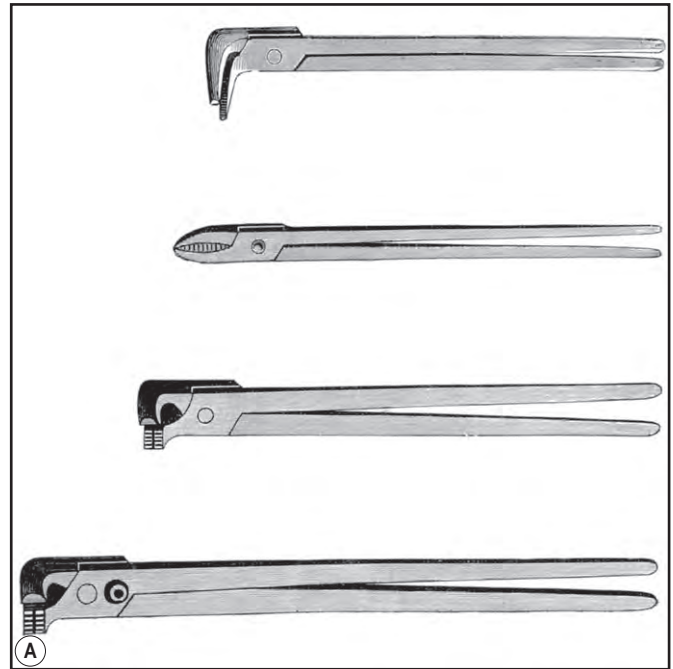


Fig. 2.10 Equine extraction forceps designed by Gunther. (A) Extractor forceps, breaking forceps, first lower molar forceps, first upper molar forceps. (B) Upper molar forceps and lower molar forceps. (Regional Veterinary Surgery 1904, pp 48–49.)

behind the jaws (similar to scissors). His model sold unmodified from 1889 until the 1970s and is still often used in Europe today. In 1895, Chicago veterinarian Herman Haussmann invented and patented the first mouth speculum featuring interchangeable incisor and gum plates as well as poll straps and upper and lower jaw straps. Previous mouth speculums utilized plates which rested on the bars of the mouth. J. Gordon McPherson of Toronto, Canada, patented a speculum in 1901, which provided improved holding of interchangeable incisor plates and secured ratchets used for adjusting the speculum.⁸

Scientific explanation did not always dominate advancements in actual dental practice during the late 1800s. Many

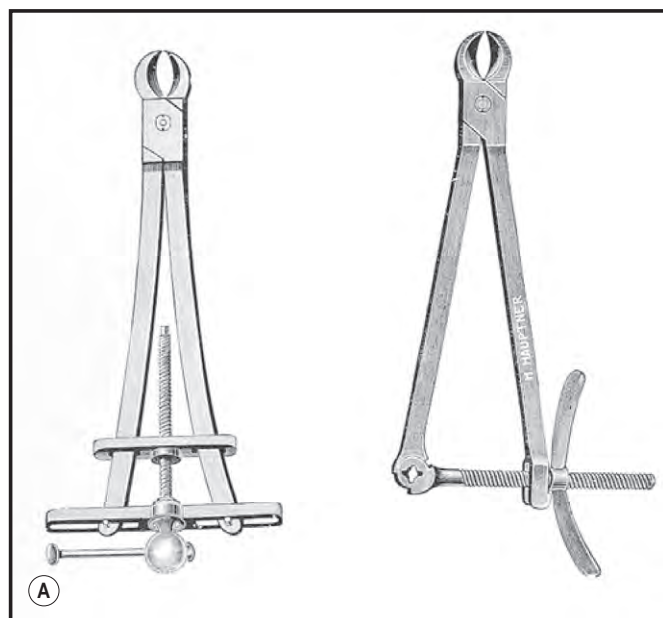


Fig. 2.11 (A and B) Moller's shears were introduced to reduce tall teeth. The central screw ensures great power without disturbing the position of the instrument. It was recommended to cast the horse and insert a rather large mouth gag before trying to cut the tooth. If the shears slide off the sides of the back molar, Moller's tooth screw may preferably be employed. (Moller & Dollar 1904, pp 36–37.)

dental practitioners retained the information passed down from previous generations, yet still managed to leave their mark on history. One example of this was Fredrick Osbourne, known then as Sydney Galvayne, an Australian veterinary surgeon and horse breaker, who arrogantly claimed to 'age

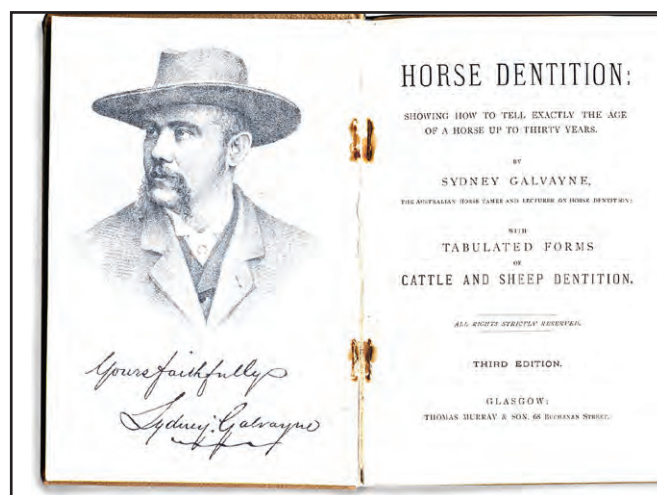


Fig. 2.12 Inside cover of Galvayne's text on dental aging, first published in the early 1880s.

any horse to within one year of its true age' (Fig. 2.12).¹⁵ He traveled throughout Europe and Australia during the 1880s. Galvayne's Groove is still used today to aid in equine aging.¹⁶ Many of Galvayne's materials were plagiarized from previous authors. Girard gives a detailed explanation of the changes in equine dentition from birth through eight years of age.¹² In 1832, Delabere Blaine described the art of aging a horse by its teeth (Fig. 2.13). He was the first to explain that the disappearance of the 'cups' or 'marks' on the occlusal surfaces of the incisors in the 3–10-year-old horse was not from 'filling up from the bottom' but in fact from the incisor teeth wearing down.¹⁷ Edward Mayhew, an early member of the Royal College of Veterinary Surgeons, published a text in 1848, *The Horse's Mouth and Showing the Age by Teeth*. This book contained many fine color plates showing the teeth of various aged horses (Fig. 2.14). He also described several dental wear abnormalities and how to correct them with 'chisel and mallet'.¹⁸ J. N. Navin, author of an 1867 American text, stated in the chapter on aging, 'the back teeth or grinders, may indeed be referred to and with considerable accuracy, but they are too far from view and so difficult to expose as to render their examination impractical'.¹⁹ About this period of time, an American veterinarian, Professor Oscar R. Gleason, published a 'new method' and poem to help horsemen age horses by their dentition (Fig. 2.15).²⁰

In 1879, William H. Clarke wrote an extensive, well researched text, *Horses' Teeth: a treatise on their mode of development, anatomy, microscopy, pathology, and dentistry; compared with the teeth of many other land and marine animals, both living and extinct; with a vocabulary and copious extracts from works of odontologists and veterinarians*. This text devoted a full chapter to dental cysts and supernumerary teeth (Fig. 2.16). Clarke gives detailed descriptions of over 60 cases of dental temporal cysts reported since this condition was first accurately described by Mage Grouille in 1811.²¹

L. A. Merillat, author of the popular *Animal Dentistry and Diseases of the Mouth*, first published in 1906, pioneered

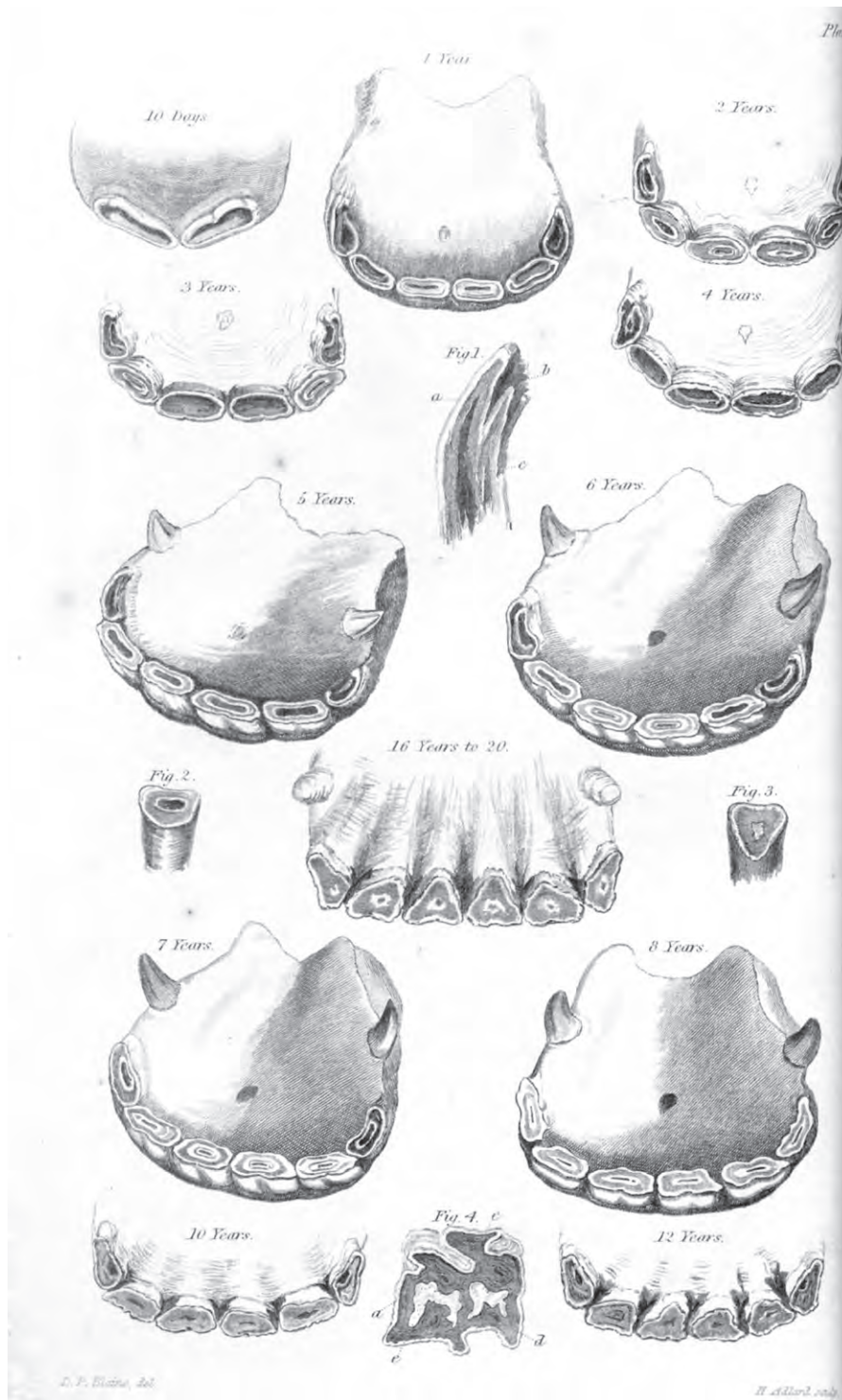


Fig. 2.13 Aging by the teeth. (D.B. Blaine, 1832.)

many unique dental surgical procedures. He was highly regarded and considered to be 'one of the foremost veterinary surgeons in this country,' who 'has in the intervals of active practice given his colleagues the benefit of his close study and large experience in the treatment of the organs concerned in the mastication.'¹¹ His advanced publication was the first to summarize dental procedures into nine categories:

1. The cutting and floating of the enamel points of the horse and ox
2. The removal of projections which prevent perfect apposition of the dental arcades of the horse, ox and hog
3. The treatment of secondary nasal catarrh resulting from diseased teeth
4. The extraction of all diseased teeth of all animals



Fig. 2.14 Color plate, aging by the teeth. (Mayhew, 1850, The horses' mouth, The teeth.)

Remember This.

To Tell the Age of Horses.

**To tell the age of any horse,
Inspect the lower jaw, of course.
The sixth front tooth the tale will tell,
And every doubt and fear dispel.**

**Two middle "nippers" you behold
Before the colt is two weeks old.
Before eight weeks, two more will come ;
Eight months, the "corners" cut the gum**

**Two outside grooves will disappear
From middle two in just one year.
In two years from the second pair ;
In three the corners, too, are bare.**

**At two, the middle "nippers" drop ;
At three, the second pair can't stop.
When four years old, the third pair goes ;
At five a full new set he shows.**

**The deep black spots will pass from view,
At six years, from the middle two.
The second pair at seven years ;
At eight the spot each "corner" clears.**

**From middle "nippers," upper jaw,
At nine the black spots will withdraw.
The second pair at ten are white ;
Eleven finds the "corners" light.**

**As time goes on, the horsemen know,
The oval teeth, three-sided grow ;
They longer get, project before,
Till twenty, which we know no more.**

—GLEASON.

Fig. 2.15 Gleason's poem for aging horses by their teeth (1892).

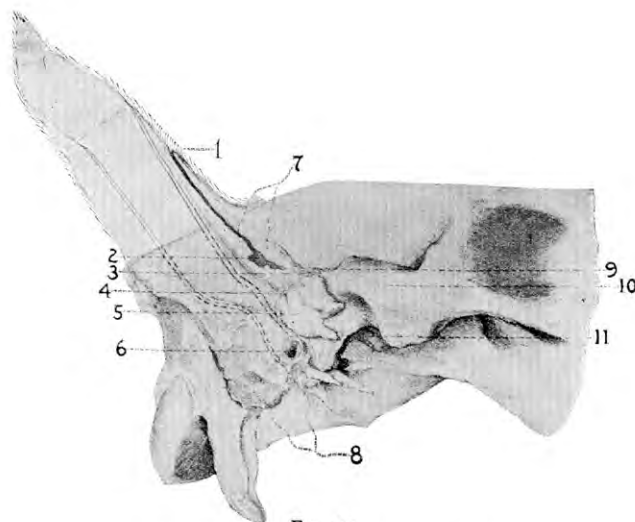


FIG. 149.

Dental Teratoma and Conchal Fistula. (Williams).

1. Mouth of the conchal fistula.
2. Bottom of the fistulous tract.
3. Gubernaculum dentis.
4. 9. Bony plates from the temporal bone
5. The tooth.
6. External auditory meatus.
7. Wall of the fistulous tract.
8. Petrous temporal bone.
10. Zygoma.
11. Temporo-maxillary articulation.

Fig. 2.16 1905 ear tooth diagram (Merillat).

5. The removal of tumors related to the teeth in all animals
6. The treatment of stomatitis caused by the bit or by dental projections
7. The amelioration of driving defects resulting from dental irregularities in the horse
8. The treatment of faulty eruptions of the permanent or temporary dentures in the dog, the horse, the ox and the cat
9. Improving the appearance of the incisors of the horse.

Interestingly, in another example of history repeating itself, Merillat is also quoted as saying, 'the veterinarian consigned dental operations to others because it is rather beneath the dignity of the learned veterinarian to float the teeth of horse, not because it is difficult, tedious, or dangerous but because animal dentistry is regarded as a trifling accomplishment that the uneducated can master.'²²

Toward the end of the 19th century in the USA, bogus veterinarians such as 'hoss doctors,' 'cow-leeches,' and 'quack doctors' appeared to dominate the medical field, outnumbering licensed veterinarians.²³ By 1900, 14 of approximately 30 veterinary schools in the USA, most of which were private institutions, closed their doors. From 1901 to 1930, of an additional 13, seven failed, including a state veterinary college. Before the beginning of WWI, 14 veterinary schools,

all of which were private, remained in the USA but many closed as students and faculty left to fight. By 1921, there were only three private veterinary schools left, with the last closing its doors in 1927. Although short-lived, these private institutions provided North America with over 10 000 veterinarians. Some of these institutions offered a correspondence-earned diploma, leading to fraudulent education and a few arrests. The Detroit Veterinary College, Inc., formed in 1905, offered correspondence courses in veterinary dentistry which were described in an elaborate advertisement (Fig. 2.17). Another veterinary dental college in St Louis was created in 1905. Neither school kept their doors open for long.¹²

C. D. House was an unqualified non-veterinarian, who is often referred to as one of the founders of American equine dentistry. In 1891 C.E. Sayre described House in the *Review*

as unqualified but as having improved some operations in horses' mouths without the use of a speculum. House was also praised for developing new instruments which have remained unaltered since William Hope's in 1596. However, Sayre did mention the danger House posed by possibly tempting other 'lay-people' into equine dentistry and potentially leading to disastrous results. House was also mentioned in texts by William H. Clarke, the well-known veterinarian and author who questioned 'skill versus brutality' in his first book, *Horse's Teeth*, in 1879. Clarke's book references House often, commenting that he was an American equine dentist practicing mainly in Connecticut and Massachusetts. Apparently, House earned a graduate degree sometime between the 1st and 3rd editions (1879–1886) of Clarke's book and was mentioned to have obtained a diploma.²¹

American equine veterinary dentistry soon became a politically complicated profession. In 1896, a French-educated veterinarian, Professor Alexandre Liautard claimed Dr House led to the 'cause of much mischief and harm and injury.' Liautard went on to compliment Professor J.A. Ryder of New York, who when asked to examine the mouth of a horse having problems pulling on the bit, found that 'the anterior borders of the first two lower molars were worn and notched,' and decided to file them obliquely so that 'they would not touch each other by their front part, but form a V shape, with the base turned forward, the apex backwards.' The results were so favorable that he was asked to apply this technique to many other horses throughout the years. Liautard expressed his concern for the future of equine veterinary medicine in the *American Veterinary Review*, referencing the increased interest in technology such as the horseless carriage and bicycle.¹¹ In 1900, another American veterinarian, W.L. Williams of the New York Veterinary College, contributed his *Surgical Operations*. This text was in part a translation of works by W. Pfeiffer of the Berlin Veterinary High School with distinctly American surgical techniques of molar extractions, repulsions, and trephining the nasomaxillary sinuses being added.^{24,25} In 1906, Williams contributed his six points, dispelling American veterinary dentistry in the *Review* by addressing it as a recent trend towards urging horse owners to seek out those who interfere with the teeth of horses and an attempt has been made to dignify the practice by appellation of veterinary dentistry.

1. More has been written upon this subject in America than in all other countries combined, we have two pretentious volumes under the title veterinary dentistry, besides much current literature...
2. American veterinary colleges have attached to their faculties a professor of veterinary dentistry and presumably give a special course in that subject. Great stress is laid upon this feature in the announcement of some of the shorter course veterinary colleges...
3. A perusal of the catalogues of the manufacturers of veterinary instruments shows a special emphasis upon dental apparatus by American firms as compared with foreign houses...
4. Graduates of American veterinary colleges largely advertise themselves as specialists in dental work...
5. American horse owners, trainers, coachmen, and stablemen have been firmly led to believe that a very

Lecture 1

How to Approach and Examine a Horse's Mouth.



Fig. 1.
Showing how to approach and examine a horse's mouth.

ALWAYS approach a horse quietly, give him a few pats on the nose and watch at the same time the expression on his face. In case you think he is liable to be vicious and strike with the front feet, be careful. It is also a good plan to enquire if the horse is inclined to be vicious or ugly with strangers, then if necessary you can take extra precaution for your own safety. If he is inclined to be ugly, place a twitch on his nose and have some one hold up one front foot. If he is of a gentle disposition, this is not necessary.

Fig. 2.17 How to approach and examine a horse's mouth. Fig. 1 Illustrated Lectures, Part II, Detroit Veterinary College, Inc., Detroit, Michigan. This mail order correspondence course advertised that veterinary dentists with a diploma could make from \$1500 to \$3000 a year in 1900.

Dentistry Was a Fad.—All horses had to have their teeth trimmed with cutters and smoothed up with a float once a year at least. It was customary to shorten the upper incisors also. They prevented contact of the molar dentures it was believed. This theory, easy as it was to disprove, could not be successfully contradicted in the horse circle of the '80's. It was easier to trim incisors and collect fees than to give a lecture on dental anatomy without pay. The teaching of House who trimmed and filed the teeth of all the horses and mules of the army during this period

Fig. 2.18 An explanation of equine dental practice given by Louis Merillat 30 years after publication of his original text on equine dentistry. (Veterinary Military History, Vol 1, 1935.)



De luxe transportation in the Yellowstone National Park in the '90's.



Dentistry in the Yellowstone National Park in the '90's.

set the example and started a practice that was as much overdone in the '80's and '90's as it is now neglected.

large proportion of the diseases and vices of horses are referable to defective teeth and the veterinary dentist is sought as a universal panacea...¹¹

These general thoughts continued to cause problems in the equine industry for many years and were addressed again in 1935 by Louis Merillat in his review on the military history of veterinary medicine (Fig. 2.18).²⁶

Education during four decades of war

The introduction of automobiles, trucks, and tractors (thus, the reduced need for horses) and a better understanding of infectious diseases at the turn of the 20th century prompted a change in veterinary textbooks as emphasis was shifted from equine to food animals and pets. Many of the overall advancements in veterinary medicine arrived through the discovery of bacteria by Pasteur, Fleming, and McFayden during the late 1800s and early 1900s. Other applications such as the use of barbiturates in veterinary patients in 1902, flexible endotracheal tubes in 1914, and anesthesia in the form of pentobarbital and penthal in 1931 and 1934 encouraged veterinary surgery to take on new challenges.⁴ Equine veterinary interest shifted back to Europe as WWI ended and WWII began (Fig. 2.19). By this time the United States Army Cavalry contained only 50 000 horses whereas the German army utilized 2.5 million.

Erwin Becker (1898–1978), a cornerstone in the advancement of dentistry techniques, served in the German army during WWI. Initially interested in pursuing an advanced engineering education, his veterinarian uncle, Helmar Dun,

convinced his nephew to pursue a career in veterinary medicine. Becker was the first to promote the importance of performing dental examinations on every patient seen in his uncle's practice using a set of stocks which he constructed (Fig. 2.20). In 1937, Becker created an improved mouth speculum with a panic bolt, interchangeable bite plates, and upholstered round bars that could be positioned over the incisors and edentulous parts of the jaws. During the period before the use of sedation, this improved speculum was helpful, working with two threaded spindles to aid in opening. Becker also worked on production of the first mechanical motor-driven float system to improve arcade corrections and consequently reduce treatment time. This power grinding equipment also featured the use of water-cooling during some procedures, thus preventing pulpar thermal insult to an area. This potentially pathological process still receives research attention today.⁸

Summaries of Becker's work, instrumentation, and experience with pathological findings were published in *Neuzeitliche Zahnbehandlung beim Pferd* in 1938. Research by G. Leue (cited by Becker), measured the lateral jaw excursion of horses fed different types of forages and grain.²⁷ Becker claimed that a study of 50 000 Cavalry horses showed that regular dental care saved 1.5 kg of oats per horse, per day, which was a desirable concept due to food shortages in Germany at the time.

Becker was conscripted into military work before WWII and moved to military headquarters at Salzburg. This establishment was taken over by American troops and Becker maintained a prisoner of war status until June 16, 1945, following which he stayed on at the equine hospital to train



Fig. 2.19 A complete set of United States Army equine dental instruments manufactured by Sharp and Smith Co., Chicago, 1915–1945. This set of steel chrome plated instruments came with interchangeable handles and was packaged in a canvas roll for ease of inventory control and reduced weight for shipping.

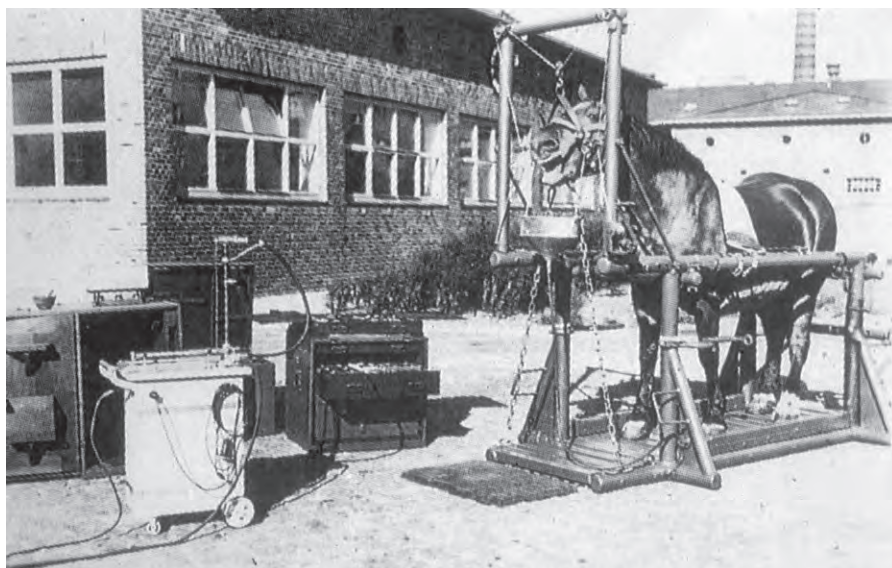


Fig. 2.20 The stocks and motorized equine dental system developed by Erwin Becker in the 1930s. A high quality black and white movie shows the dental tools in use and other Becker innovations such as the taking of dental impressions and making plaster models of dental abnormalities. (*Einmal im Jahr, Ein Lehrfilm* von Prof. Dr Erwin Becker, Equivet, Kruuse, Denmark.)

American veterinary students serving in the army. Eventually, Becker returned to Berlin to continue his career at the American Cavalry and Riding Center, until 1959. The largest collection of Becker's equine dental findings may be found in Joest's *Handbook on Pathological Anatomy* published in 1970.⁸

A new interest is born

In 1931, the Dental Board of the UK published a text containing four lectures by Sir Frank Colyer regarding *Abnormal Conditions of the Teeth in Their Relationship to Similar Conditions in Man*, which was based on observations of museum specimens from Europe and the USA. In 1936, Colyer published what is considered the preeminent text on animal dentistry, *Variations and Diseases of the Teeth of Animals* which included over 1000 pictures of dental abnormalities, many

of which are equine.²⁸ Professor Hugo Triadan, a human dentist, opened a dentistry suite in a veterinary facility in Bern, Switzerland in 1970. His experience led to the development of the Modified Triadan system and dental charting used today.²⁹

The second half of the 20th century brought the revival of interest in horses for sport and recreational purposes. With the increase in horse numbers, equine veterinary practitioners began to realize the importance of forming a unified group with which to share knowledge. The American Association of Equine Practitioners was formed in 1954 and the British Equine Veterinary Association in 1961. Despite the renaissance of equine veterinary work at the time, little emphasis was given to equine dentistry in the 1960s with the exception of Hofmeyer's South African publication of comparative dental pathology and Honma's Japanese study of dental caries in domestic animals.^{30,31}

Throughout the 1970s and 1980s, with the increased encouragement of horse trainers and owners, interest was spurred regarding dentistry affecting performance and dietary supplementation. This consequently led to the development of new dental instrumentation such as advanced power floats. Improved methods and drugs for standing sedation allowed veterinarians the ability to perform safe and effective oral examinations and procedures. With the advancement of technology and technique, research on equine dental disorders should have followed, but it was difficult to prioritize dollars for graduate study and training devoted to equine dentistry. Following the formation of the American Veterinary Dental Society in the United States in 1976, the Academy of Veterinary Dentistry, and American Veterinary Dental College in 1987, awareness increased, but books with texts on equine dentistry contained no new scientifically-based knowledge. Many veterinary dental texts of that time mainly contained information on small animal dentistry, with a few containing limited chapters referencing equine dentistry: Zetner 1982, Harvey 1985, d'Autherville & Barrairon 1985, and Kertez 1993.⁸

Several important modern technological improvements in equine dentistry were developed in the 1980s and 1990s. Soon after the interchangeable carbide chip blade replaced the steel Dick float blade, Don Matlock introduced the solid carbide float blade. During this time three breakthroughs in motorized dental equipment occurred with the introduction of the rotary disk power tool in Europe by Eisenhut, the guarded flexible shaft grinder in Argentina by Estrada, and the short stroke oscillating float by Stubbs (Figs 2.21 & 2.22).

Original evidence-based scientific research on equine dentistry finally began in the late 1970s. In 1979, Dr Gordon Baker completed his PhD thesis on equine dental anatomy and development in health and disease.³² He continued to teach this topic throughout his professional veterinary surgical career. In 1989, Larry Moriarity started a discussion on the evaluation of incisor alignment and occlusal contact during lateral jaw movements which was later modified by Drs Scrutchfield, Rucker, and DeLorey.^{33,34,35} During the mid-1990s Professor Paddy Dixon and his associates began what is considered the 'renaissance' of equine dentistry through research conducted at Edinburgh University, Scotland. He not only promoted the general practice of equine dentistry but emphasized the need for advanced species-specific research to be performed in order to provide scientific

knowledge for many current trends and practices that were born out of fiction and superstition. Many of these traditional techniques, including incisor reduction and wolf teeth extraction continue to be used in modern times.³⁶

One such previously unquestioned practice was the use of aging from dental appearance which can be traced back to China in 600 BCE. In 1993, Walmsley's studies initially questioned the accuracy of aging horses through dentition, and from 1994–1995 the work of Richardson, Cripps, and Lane further confirmed the inaccuracy of aging by dentition.^{37,38} With an increase in evidence-based medicine and research the field of equine dentistry continued to develop. During 1996–1998, Muylle and colleagues conducted extensive research on the gross histology of age-related changes in equine incisors.^{39,40} In 1998, an equine dentistry issue of the *Veterinary Clinics of North America* edited by Gaughan and deBowes was released. Along with the 1999 first edition of *Equine Dentistry* by Baker and Easley, these texts represented the only two professional veterinary publications on equine dentistry since Becker's 1938 book.⁸ Not only did research take on new challenges, but the opportunities within clinical practice began to expand as ideas flourished and prospects for new procedures grew. The first decade of the 21st century saw the introduction of endodontics, orthodontics, periodontology, and restorative dentistry into the equine field. Diagnostic capabilities also provided new areas of interest and created innovative avenues through which



Fig. 2.21 Estrada's flexible shaft rotary tooth grinder with a guarded burr. This tool was patented in the 1960s and distributed in the United States by Jorgenson, Co.



Fig. 2.22 The Makita rechargeable battery powered oscillating dental float with an adjustable head was introduced in the 1980s.

dental problems were addressed and treated. Contemporary digital radiograph systems including intraoral radiography allowed for detailed studies of dental tissues and computed tomography imaging increased the imaging capabilities of the head and assisted with planning intricate treatment modalities.^{41,42}

As interest through research, clinical capabilities, and advanced diagnostics reached new horizons, the need for specialized groups focusing on the care and challenges associated with equine dentistry emerged. AAEP president Dr Clyde Johnson in 1996 appointed Drs Lowell Smalley, Leon Scrutchfield, and Dean Scoggins as the equine dental committee chairs for a group involved with the promotion of good equine dental care through advanced education, wet laboratories, and programs involving equine practitioners, veterinary students, and clients. Since that time, the combined efforts of veterinary associations, universities, and national organizations, in particular the American Association of Equine Practitioners (AAEP), the British Equine Veterinary Association (BEVA), the Canadian Veterinary Medical Association, and the Australian Association of Equine Practitioners have held over 200 short courses and wet laboratories to train thousands of equine veterinarians in basic and advanced dental techniques.

In 2001, the Academy of Veterinary Dentistry established an equine credentialing tract where two fellows eventually became recognized. The American Veterinary Dental College has since formed a committee to establish the criteria necessary to obtain equine dentistry diplomates. The most recent and significant collaboration of equine veterinarians practicing the art of dentistry occurred in 2006 when the AAEP and BEVA held a joint conference titled 'Focus on Dentistry'.

Forty-nine scientific equine dental papers were presented to over 400 international veterinarians in attendance (see 'Focus on Dentistry'; <http://www.ivas.org>).⁴³

Although veterinarians' interests in adding or expanding equine dentistry within their practices are escalating, the old struggle between lay tooth floaters and veterinarians continues to be a heated and debated topic. In 2000, BEVA and the British Agriculture Ministry developed a program to train and test for licensure, equine dental technicians to perform basic oral examinations and carry out minor dental corrections.

The results of the 2005 AAEP survey showed that 79% of veterinarians provided some dental service to their clients with 30% examining at least 200 horses per year. However, of the 21% of veterinarians who did not see any dental cases, 48% admitted referring their clients to non-veterinarians for dental care.⁴⁴ This is not a new issue, as evidenced throughout the rich pages of history regarding the care of horses' teeth. Equine dental technicians have historically and currently blurred the line between veterinarian and lay person, but it is important to recognize the limitations of all parties. Ultimately, the goal should be improvement of the quality of care for the horse. If this goal is diminished or lost, our patients suffer and we as professionals risk being doomed to repeat history's mistakes.

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References

- Percivall W. Part second of a series of elementary lectures on the veterinary art: wherein the anatomy, physiology, and the pathology of the horse are essayed on the general principles of medical science. Longman, Hurst, Rees, Orme, Brown and Green, London, 1824, p 20
- Yount W. The horse, with a treatise of draught, 1st edn. Baldwin and Cradock, London, 1846, 31: 146, 202
- Dick W. Manual of veterinary science. Adam and Charles Black, Edinburgh, 1862, p 76
- Harvey CE. The history of veterinary dentistry, part one: from the earliest record to the end of the 18th century. *J Vet Dent* 1994; 11(4): 135–139
- The Literary Encyclopedia. Online. Ancient texts translations. Available: <http://www.litencyc.com/index.php>
- Bennett D. The evolution of the horse. Horse breeding and management. Elsevier, Amsterdam 1992, pp 1–29
- Kertesz P. Color atlas of veterinary dentistry and oral surgery. Wolfe Publ., Aylesbury, UK, 1993
- Fahrenkrug P. The history and future of equine dental care. In: Proceedings from the North Am Vet Conf, Orlando 2005, pp 51–154
- Easley K. Veterinary dentistry: its origin and recent history. *J Hist Dent* 1999; 47(2): 83–85
- Smithcors JF. Evolution of the veterinary art. Vet Med Pub Co, Kansas City, 1957, pp 161–171
- Bierer BW. American veterinary history, 1st edn. Olson C, Fort Dodge, Iowa, 1980, pp 6, 8, 43, 54, 118–120, 128, 131–133, 143
- Girard J. Traité de l'âge du cheval, 3rd edn. Béchot Jeune, Paris, 1835, pp 8–37
- Lopez T. One hundred years as the AVMA. *J Am Vet Med Assoc* 1998; 212(1): 9
- Hinebauch TD. Veterinary dental surgery. LaFayette, Indiana, 1889, pp 224–239
- McCarthy PH. Galvayne: the mystery surrounding the man and the eponym. *Anat Histol Embryol* 1987; (16): 330–336
- Galvayne S. Horse dentition, showing how to tell exactly the age of a horse up to thirty years, 3rd edn. Thomas Murray, Glasgow, 1886, pp 17–27
- Blaine D. Veterinary art, diseases of the horse, 4th edn. Boosey, Longman, Rees, Brown and Green, London, 1832, pp 29–40
- Mayhew E. The horse's mouth, the teeth, 3rd edn. Fores, London, 1850, pp 69–115, 181–194
- Navin JN. Navin's veterinary practice or explanatory horse doctor. Roach, Indianapolis, 1867, p 443
- Gleason OR. Gleason's horse book and veterinary advisor.: Donohue, Chicago, 1892, pp 224–240
- Clarke WH. Horses' teeth, 3rd edn rev.: WK Jenkins, New York, 1886, pp 113–129, 198–202
- Merillat LC. Veterinary surgery, Vol 1. Animal dentistry and diseases of the mouth: Aberouder Eger, Chicago, 1916, pp 16–17
- Lemons LL. A century of veterinary medicine in Nebraska, 1st edn. Service Press, Henderson, 1982, pp 13–17
- Williams WL. Surgical and obstetrical operations. Ithaca, New York, 1900, pp 1–41
- Moller H, Dollar JAW. The practice of veterinary surgery Vol. III. Regional

- Surgery, Jenkins, New York, 1904, pp 1–74
26. Merillat L, Campbell D. Veterinary military history of the United States, Vol 1. Haver-Glover Laboratories, Kansas City, 1935, p 295
 27. Leue G. Cited by Becker E. 1962. Zahne. In: Dobberstein J, Pallaske G, et al. Handbuch der speziellen pathologischen Anatomie der Haustiere, Vol V, 3rd edn. Paul Parey, Berlin, 1941, pp 131–132
 28. Miles AEW, Grigson C. Colyer's variations and diseases of the teeth of animals. Cambridge University Press, Cambridge, 1990, p ix
 29. Floyd MR. The modified triadan system: nomenclature for veterinary dentistry. *J Vet Dent* 1991; 8(4): 18
 30. Hofmeyer CFB. Comparative dental pathology (with particular reference to caries and paradental disease of the horse and dog). *J So African Vet Med Assoc* 1960; 29: 471–480
 31. Honma K, Yamalawa M, Yamauchi S, Hosoya S. Statistical study on the occurrence of dental caries in domestic animals. In: *The Horse*. *Jpn J Vet Res* 1962; 10: 31–36
 32. Baker GJ. A study of dental disease in the horse. PhD thesis, University of Glasgow, Glasgow, 1979, pp 42–56
 33. Scrutchfield WL. Incisors and canines. *Proc Am Assoc Eq Pract* 1991; 37: 117–121
 34. Rucker BA. Modified procedure for incisor reduction. *Proc Am Assoc Eq Pract* 1995; 41: 42–44
 35. DeLorey M. A retrospective evaluation of 204 diagonal incisor malocclusion corrections in the horse. *J Vet Dent* 2007; 24(3): 145–149
 36. Dixon PM. Equine dental disease: a neglected field of study. *Eq Vet Edu* 1993; 6: 285–286
 37. Walmsley JP. Some observations on the value of ageing 5–7 year old horses by examination of their incisor teeth. *Eq Vet Edu* 1993; 5: 295
 38. Richardson JD, Cripps PJ, Lane JG. An evaluation of the accuracy of ageing horses by their dentition: can a computer model be accurate? *Vet Rec* 1995; 137(6): 139–140
 39. Muylle S, Simoens P, Lauwers H. Ageing horses by examination of their incisor teeth: an (im)possible task? *Vet Rec* 1996; 138: 295–301
 40. Muylle S, Simoens P, Lauwers H, Van Loon G. Ageing Arabian horses by their dentition. *Vet Rec* 1998; 142: 659–662
 41. Klugh DO. Intraoral radiology in equine dental disease. *Clin Tech Eq Pract* 2005; 4: 162–170
 42. Pulchalski S. Computer tomographic and ultrasonographic examination of equine dental structures: normal and abnormal findings. *Proc Am Assoc Eq Pract, Focus on Dentistry*. Indianapolis, Indiana, 2006
 43. Galloway S, Easley J. Establishing a scientific basis for equine clinical dentistry. *Vet J* 2008; 178(3): 307–310
 44. AAEP Survey. Practitioners' survey, unpublished. American Association of Equine Practitioners, Lexington, KY, 2005

Bits, bridles and accessories

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Introduction

A veterinarian must understand the action and purpose of bridles, bits, and accessories (e.g., nosebands and martingales) not only to provide optimal health care to horses' mouths but also to effectively communicate with owners and trainers and to address their concerns about their horses' performance.¹ We must be aware of what a horse does for a living, become familiar with what is expected, and provide the kind of dental care required to help horses perform most comfortably and at their best.²

Refinements in the way that teeth should be floated depend both upon the job of the horse and the type of bit used. The biting requirements are different for western performance, English pleasure, polo, jumping, dressage, racing, equitation, driving, etc. For example, the D-ring snaffle is a popular bit for Thoroughbred racing, in which the jockey's hands are above the horse's neck, but this bit is seldom used in Standardbred racing because the angle of pull on the reins of a driving horse is straight back towards the driver.

The second premolars of a racing Thoroughbred, whose chin must extend to achieve maximum speed, require more rounding than those of a pleasure horse who performs in a nearly vertical head set (compare Fig. 3.1E with Fig. 3.1A and Fig. 3.3C with Fig. 3.3A). The removal of wolf teeth is of more obvious advantage for harness horses with overcheck bits than it is for pleasure horses.^{1,3,4,5} (Compare Fig. 3.3A with Fig. 3.19.) A barrel-racing horse in a gag bit requires a deeper bit seat than a cutting horse in a grazer curb bit (compare Fig. 3.7B with Fig. 3.9D).

Proper use of bits and bridles

Bits and bridles are for communication. They are not handles to stabilize the rider in the saddle or instruments for punishing the horse.⁶⁻⁸ The western horse is ridden with slack in the rein while the English horse is generally ridden with more contact with the bit, but in either case the accomplished rider uses his seat and legs before his bit to communicate his wishes to his mount. Indeed, the most important factor in having soft, sensitive hands on the reins is developing a good seat.⁹

Of course, for the driver of the horse in harness, communication via the seat and legs is not an option. Discounting the relatively minor role of the whip, the bridle and reins or lines (the proper name for the reins of a draft horse) are the only nonverbal means of communication and thus assume even more importance than they do in the ridden horse.¹

As with all methods of training and communicating with the horse, the key to the proper use of bits and bridles is the principle of pressure and release.⁶⁻⁹ A horse does not intuitively move away from pressure. Rather, he learns to seek a position of comfort to relieve the pressure applied by the bit in his mouth. Consequently, the rein pressure must be released the instant that the horse complies (or even tries to comply) with the request sent to him via the bit. If the pressure is not released, the horse has no way of knowing that his response was correct and becomes confused.⁶⁻⁹ When a rider or driver applies rein pressure, he is asking the horse for a response; when he releases the pressure, he is thanking the horse for complying.^{6,9}

Bits, bridles, and accessories can exert pressure on a horse's mouth bars (the horseman's term for the lower interdental space), lips, tongue, hard palate, chin, nose, and poll. Of these, the tongue and the hard palate are the most sensitive and the most responsive to subtle rein pressure. Depending upon the type of headgear used, however, commands sent to the horse via the bars, lips, chin, or nose can be more important than those transmitted via the tongue and palate.

An important concept in biting is signal, which is defined as the time between when the rider or driver begins to pull on the reins and the time when the bit begins to exert pressure in the horse's mouth. As a horse becomes schooled, he learns to recognize the initial increase in rein pressure and to respond before significant pressure is applied.⁷

Signs of biting problems

Although cut tongues are the most obvious injuries associated with the improper use of bits, less spectacular injuries to the bars and other tissues are also signs of biting problems. Tissue trapped by a bit may bunch between the bit and the first lower cheek teeth where it is pinched or cut. The damaged area may then be irritated every time the bit moves.¹ Trauma to the lower interdental space frequently



Fig. 3.1 The proper head carriage when a horse is 'on the bit' varies depending upon the function of the horse. (A) The pleasure horse with a nearly vertical head set is collected, that is, his weight is shifted to the rear. (B) The draft horse pulling a heavy load may carry his head more vertically. (C) This horse is 'behind the bit,' overflexing his chin to his chest to evade bit pressure. (D) The racing Standardbred needs to extend his nose to achieve speed but his head position must be controlled to keep him on gait. (E) The racing Thoroughbred, in order to achieve maximum speed, must be able to fully extend his nose and shift his center of gravity forward. (F) This horse is 'ahead of the bit,' overextending his chin to evade bit pressure.

penetrates to the mandible with resulting mandibular periostitis.^{8,10,11–15} All types of headgear can press the lips and cheeks against points or premolar caps on the upper cheek teeth.¹

Most bit-induced wounds are superficial, heal rapidly due to the extensive blood supply to the mouth and the antibacterial action of saliva, and seldom require treatment.^{11,16} A severely lacerated tongue, however, often heals with a permanent defect, and mandibular periostitis, in severe cases, can lead to the formation of osseous sequestra.^{10–13,17,18}

A horse with a sore mouth or improperly fitting bit will often gape his mouth and pin his ears. He may nod his head excessively or toss his head. He may extend his neck (get ahead of the bit) or tuck his chin against his chest (get behind the bit; Fig. 3.1).⁹ Biting problems can be mistaken for lameness, as when a horse fails to travel straight.

It is a common misconception that a horse with a painful mouth will be especially sensitive to bit cues. In fact horses tend to push into pain.^{2,8,9} A horse with bilaterally tender bars may root into the bit. A horse which is sore on one side of his mouth may lean on the bit on the tender side. A vicious cycle can result from attempts to gain such a horse's respect by changing to increasingly severe bits.⁶ Oral discomfort causes horses to focus on pain rather than on performance. They may fail to respond to the bit cues, may evade the action of the bit or may ignore the bit completely.²

When you are consulted about a horse that has performance problems, you should always inquire about the type of bit used and carefully examine the tongue, lips, bars, palate, chin and nose for subtle signs of injury.¹⁹ It is important to compare the left and right interdental spaces to detect subtle differences.^{10,17}

A localized soft and thickened raised area may indicate mandibular periostitis, especially if the horse reacts violently when pressure is applied to it. Techniques such as mental nerve blocks, radiographs, scintigraphy, and computed tomography may be necessary to confirm the presence of this condition in living horses. A simple surgical procedure has been described for removing the periostitis and making the horse more comfortable with his bit.¹⁰

Even in the absence of an obvious injury, a change to a gentler bit will often lead to an improvement in a horse's performance.^{8,11,13,16}

Mouthpieces

The mouthpiece of a bit may be solid or may have one or more joints. A mouthpiece made up of two or more pieces is referred to as a jointed or broken mouthpiece (Fig. 3.2A). The two halves of a simple jointed mouthpiece are called the 'cannons.' One purpose of the joint is to form a roof over the tongue, which gives the tongue some relief from the pressure of the bit. Another purpose is to change the angle of pull. As the cannons collapse, pressure is transferred from the tongue to the bars and lips. Some jointed mouthpieces (e.g., Dr Bristol and French snaffle) have an extra link between the cannons. The center link creates more room for the tongue, but changes the angle at which the pressure is applied to the tongue, bars and corners of the lips. There is more pressure on the tongue and less leverage on the bars and lips⁸ (Fig. 3.3). Of course, the position of the horse's head, which varies depending upon the horse's use, will have a profound effect upon the bit's action (Figs 3.1 & 3.3).

A solid mouthpiece may be straight, curved or ported. One of the most common misconceptions in biting is that a low port makes a mouthpiece mild and that a high port makes it severe.⁶ The error in such a conception becomes evident when we consider that the tongue is the most sensitive part of the horse's mouth and that the purpose of the port is to prevent the bit from applying the majority of its force directly to the tongue^{6,20} (Fig. 3.4). A high port is severe only if it comes into contact with the horse's palate (Fig. 3.7D). For most horses, the port must be at least 2–2.5 inches (5.1–6.4 cm) high to contact the palate.^{6,9}

A straight, solid mouthpiece can be severe because the tongue takes almost the full force of the pull. The mullen mouthpiece (Figs 3.2E & 3.12A), with its gentle curve from one side to the other, still lies largely on the tongue and gives only a small margin of tongue relief. When using a bit with

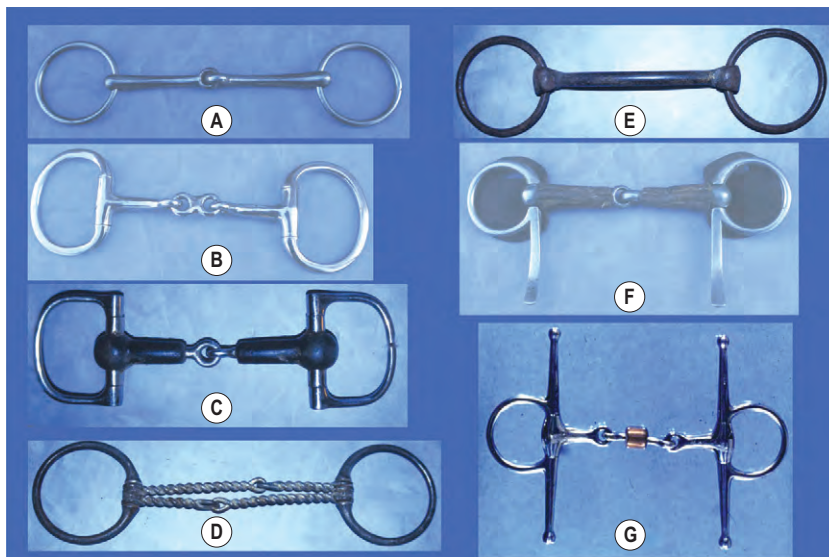


Fig. 3.2 Examples of snaffle bits. (A) O-ring with broken mouthpiece. (B) Egg butt with center link in mouthpiece. (C) D-ring with rubber covered mouthpiece. (D) Fixed ring with double twisted wire mouthpiece. (E) O-ring with solid mullen mouthpiece. (F) Half cheek with leather covered mouthpiece. (G) Full cheek with cricket in mouthpiece.

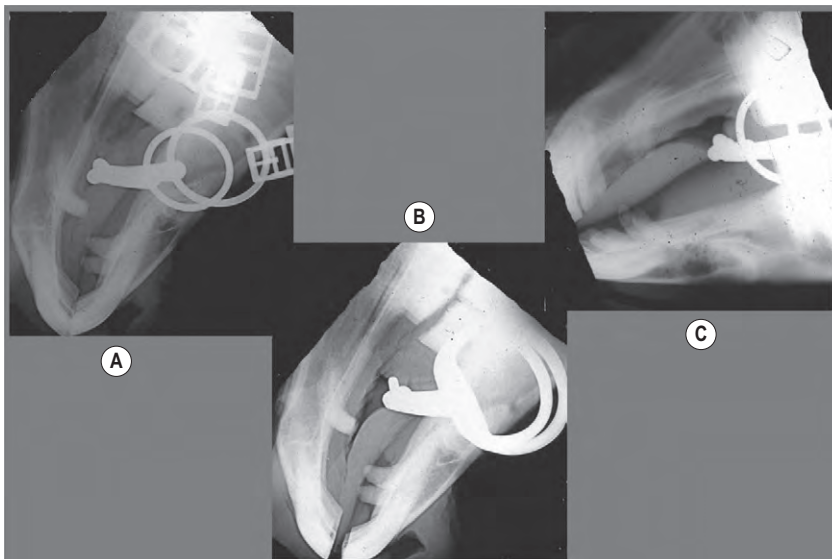


Fig. 3.3 Lateral radiographs of snaffle bits under rein pressure. (A) Broken mouthpiece, poll flexed. (B) Center linked mouthpiece, poll flexed. The extra link transfers pressure from the bars to the tongue. (C) Broken mouthpiece, nose extended. The more a horse's nose is extended, the more likely that his lips will be pinched against his teeth and his tongue will be punished by the bit.

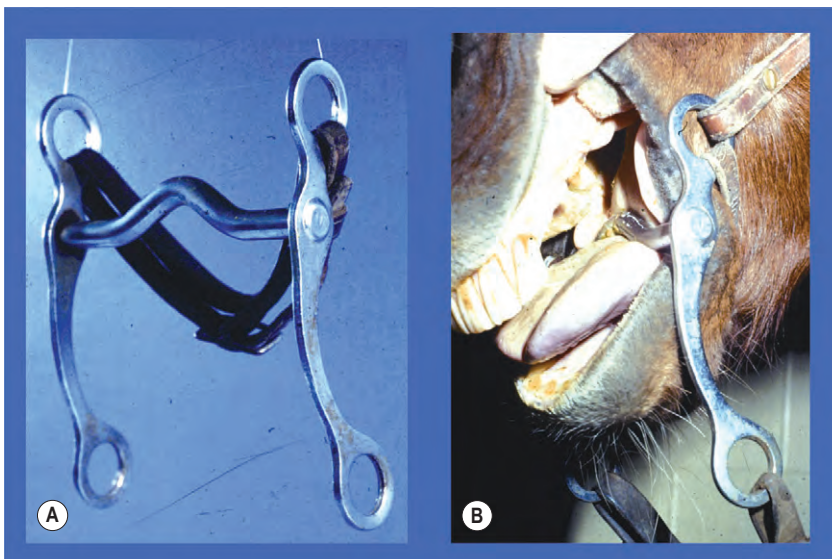


Fig. 3.4 (A) Standard curb bit. (B) The lower the port, the greater the chance that the tongue will be damaged by a curb bit.

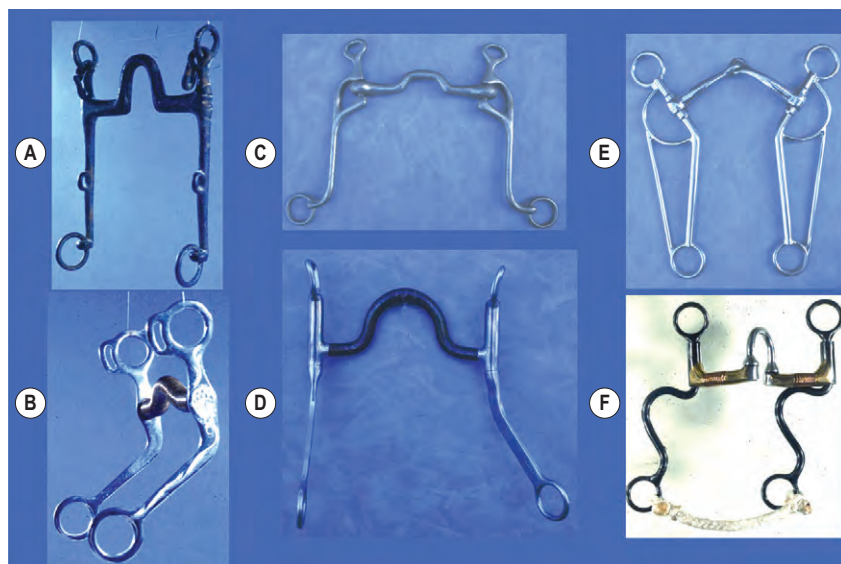


Fig. 3.5 Examples of leverage bits. (A) Straight shanked pleasure horse bit. (B) Grazer bit. (C) Loose cheeks. (D) Myler bit with fixed cheeks and independently rotating shanks. (E) Loose cheeks, broken mouthpiece. (F) Correction bit.

a straight or mullen mouthpiece, a hard jerk on the reins can easily cut the tongue.⁸

A mouthpiece's severity is inversely related to its diameter. Mouthpiece diameter is measured one inch in from the attachment of the bit rings or shanks, because this is the portion of the mouthpiece that ordinarily comes into contact with the bars of a horse's mouth. A standard mouthpiece is $\frac{3}{8}$ inch (9.5 mm) in diameter. Most horse show associations prohibit a $\frac{1}{4}$ inch (6.4 mm) (or smaller) mouthpiece because it is considered too severe.⁸ Although a $\frac{1}{2}$ inch (1.27 cm) mouthpiece is generally mild, some horses may be uncomfortable carrying so thick a mouthpiece.^{17,21} Some horses, especially Thoroughbred types, have relatively narrow, sharp bars which are easily damaged by pressure.²² Such horses require thicker and/or softer mouthpieces than do horses with thicker bars. One should always look into a horse's mouth to assure that a mouthpiece fits comfortably.⁸

Mouthpieces are constructed of many different materials and combinations of materials (Figs 3.2, 3.5 & 3.12). In order for a bit to function properly, the horse's mouth must be wet.^{8,9} Copper is frequently incorporated into mouthpieces because it is reputed to promote salivation. Cold-rolled steel, sometimes called 'sweet iron', is second to copper in stimulating salivation. Sweet iron will rust and, while it may be unattractive, rust seems to taste good to many horses and may further stimulate salivation. Rust-proof stainless steel, however, will also promote salivation to some degree and has the advantages of being hard, staying smooth and cleaning easily. Some bitmakers assert that mouthpieces which combine two different metals are superior for saliva production to mouthpieces made with a single metal. Aluminum, chrome-plated, rubber and leather covered mouthpieces are thought to produce dry mouths.

Of course the metal used in the mouthpiece is not the only factor involved in producing a wet mouth. A dry mouth, usually a result of excessive epinephrine secretion, is a sign of a stressed, unhappy horse. When it comes to generating a wet mouth, the horse's mental state is probably more important than the metal used in the bit. A severe

mouthpiece which causes the horse to worry or fret is unlikely to promote a wet mouth regardless of its chemical make-up. Some mouthpieces incorporate rollers, commonly called 'crickets,' or dangles, commonly called 'keys,' to stimulate tongue movement and thus enhance salivation. Such tongue toys also have a pacifying effect on nervous horses.

Some horsemen cover their mouthpieces with latex in the early stages of training or use rubber or leather-covered covered mouthpieces on very soft-mouthed horses to protect the bars and tongues.²³ Plastic and synthetic mouthpieces are gradually coming into greater acceptance.²⁴

The more complicated the mouthpiece of a bit and the more contact used by the rider, the greater the risk of oral discomfort and/or injuries. Smooth mouthpieces are obviously gentler than those with edges, ridges, teeth or chains.

Snaffle bits (Fig. 3.2)

Regardless of the bit they will ultimately wear, the great majority of today's horses are started in snaffle bits. Snaffle bits are used on 2–5-year-old western performance horses as well as on all classes of English riding for younger horses. Nearly all racehorses, both ridden and driven, spend their entire careers in snaffle bits.

A snaffle bit is any bit, whether it has a jointed or solid mouthpiece, in which the cheeks of the bridle and the reins attach to the same or adjacent rings on the bit.^{6,9,25} There is a direct line of pull from the rider's hands to the horse's mouth with no mechanical advantage. Tightening of the reins causes all types of snaffle bits to relocate caudally, to rotate on their long axis and to press on the horse's tongue, bars and lip corners.¹⁸

Snaffle bits often are identified by the shape of their rings (e.g., O-ring, D-ring, half-cheeked, full-cheeked) and by how their cannons attach to the rings (e.g., loose-ring, fixed ring, egg butt). All ring shapes and attachments have their advantages and disadvantages. A loose ring snaffle, in which O-shaped rings run through holes in the ends of the mouthpiece (Fig. 3.2A), affords the maximum signal. The rings

revolve freely and tend to rotate slightly when the reins are picked up but before the bit engages. However, the rotating rings can pinch the corners of a horse's mouth.

In egg butt and D-ring snaffles (Fig. 3.2B & 3.2C) a metal cylinder connects the mouthpiece to the cheek rings and prevents pinching at the corners of the mouth. The well-defined corners of the D-ring snaffle (the straight line of the D) increase the pressure on the horse's cheeks and thus the control over the horse. However, this same pressure increases the chances that the horse's cheeks will be pressed against points on the upper premolars.

Some snaffles have prongs or 'cheeks' attached to the rings (Fig. 3.2F & 3.2G). 'Full cheek' snaffles have prongs both above and below the mouthpiece, while half-cheek snaffles have prongs below the mouthpiece. Like the D-ring or cylinder type snaffles, the cheeks encourage the horse to turn in the desired direction by increasing the pressure on the corners of the mouth and sides of the face. The cheeks also prevent the bit from being pulled through the mouth. Because their rings do not rotate, all cheeked, D-ring and egg-butt snaffles provide less signal than loose ringed snaffles.⁸

Leverage bits (Figs 3.4 & 3.5)

Leverage, or curb, bits provide a mechanical advantage to the rider. There are two sets of bit rings: the upper rings attach to the headstall, and the lower rings attach to the reins. The ratio of the length of the shanks of the bit (the portion below the mouthpiece) to the cheeks of the bit determines the amount of leverage. The severity of a bit increases as the ratio increases.⁹ For example, in a standard curb bit with 4.5 inch shanks and 1½ inch cheeks (a 3:1 ratio), one pound of pressure on the reins translates into 3 pounds of pressure in the horse's mouth. When using a bit with 8-inch shanks and 2-inch cheeks, one pound of pull results in four pounds of pressure. However, regardless of the ratio, the longer the shanks, the less the force on the reins required to exert a given pressure in the mouth.⁸

Although the severity of a bit increases with the length of the shanks, this severity is partially offset by the fact that the signal provided to the horse increases as well.⁸ A long-shanked bit must rotate more than shorter-shanked bit before it exerts significant pressure in the horse's mouth.

Leverage bits are called curb bits because to exert their leverage they depend upon a curb chain or strap that passes beneath the horse's chin groove and attaches to the rings on the cheeks of the bit. The bit rotates in the horse's mouth until the curb strap stops (curbs) the rotation and the leverage action of the bit takes effect (Fig. 3.6). The leverage bit exerts pressure primarily on the chin groove, the tongue and the bars (Fig. 3.4 and 3.7).^{6,9}

The adjustment of the curb strap determines the point at which it snugs up into the chin groove, how quickly and where the bit makes contact with the mouth, and how far the mouthpiece will rotate (Fig. 3.6). The tighter the setting, the less the pull required to activate the bit. The more the bit rotates before the chin strap engages, the more the pressure is transferred to the corners of the lips and to the poll and the less to the tongue, bars and chin groove. Of course, if the bit has a high port or spoon, and the curb strap is loose, the rotation may be halted by contact with the palate, which then must bear part of the pressure.

Typically, the more moving parts within a leverage bit, the more signal it will provide to the horse.^{6,8} For example, a loose-jawed bit, one that attaches to the mouthpiece via hinges or swivels, will provide a certain degree of rotation before the bit engages. Add a loose rein ring to the loose jaw, and the bit will provide even more signal. Install a broken mouthpiece in those shanks and you amplify the signal even more.⁹ The downside of a broken mouthpiece in this type of bit is that it increases the potential severity of the bit. In a swivel ported bit, often called a 'correction' bit, there are joints on each side of the port where it joins the bars (Fig. 3.5F). Such bits are capable of exerting tremendous bar and tongue pressure.

The angle between the shanks and the cheeks affects the speed of communication. The straighter the line, the less signal the bit provides. In the so-called grazer bit (Fig. 3.5B),

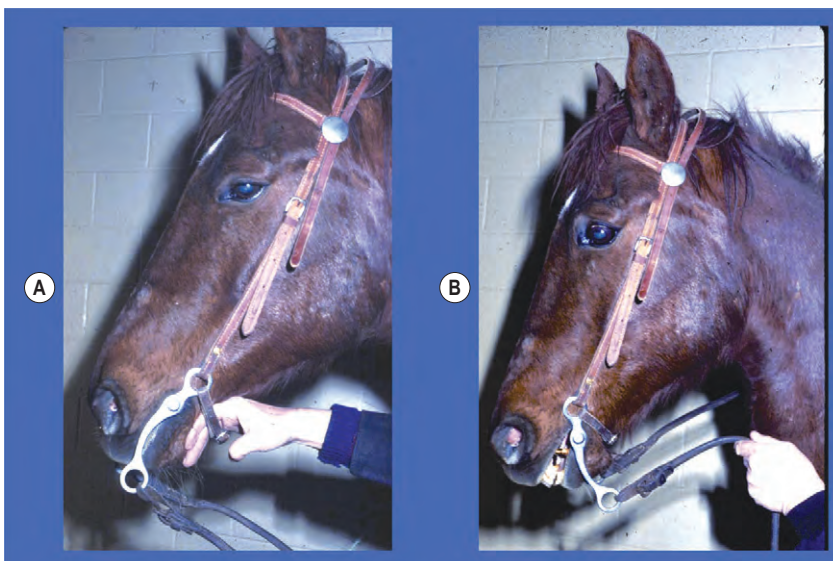


Fig. 3.6 (A) A curb strap's adjustment is often based upon the number of fingers that can be slipped under it. (B) A better way is to determine how much rotation of the bit is desired and to set the curb strap accordingly.

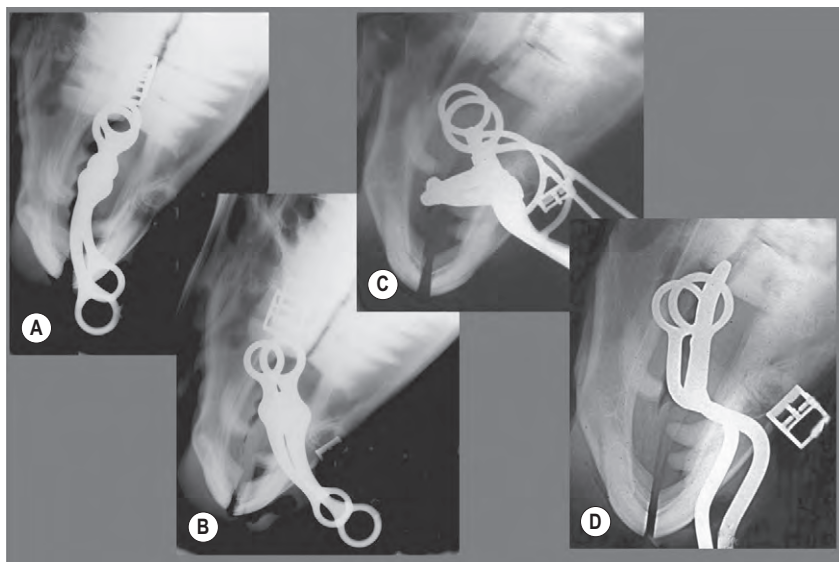


Fig. 3.7 Lateral radiographs of curb bits. (A) No rein pressure. (B) Rotation under rein pressure. (C) Rein pressure on a bit with loose cheeks and a broken mouthpiece can force the mouthpiece against the palate. (D) A bit with a high port or spoon can contact the palate, and a lateral pull of the reins can force the bit against the cheek teeth.

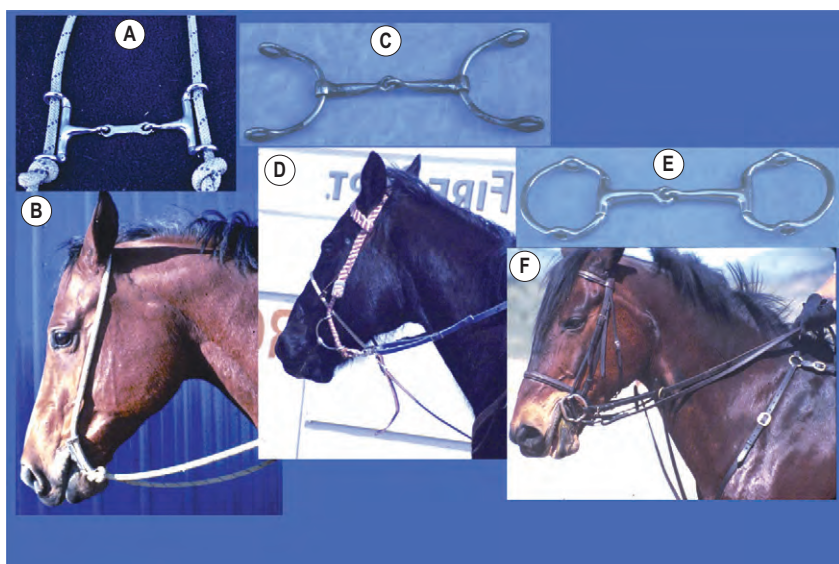


Fig. 3.8 Three types of gag bits. (A, B) Basic gag bit, in this example with a link in the mouthpiece. (C, D) Gag snaffle with half-O-rings. (E, F) Gag with full rings for attachment of snaffle rein.

with swept back shanks, the mouthpiece tends to rotate less than in a bit with straighter shanks (Fig. 3.5A) and provides more signal to the horse.^{8,9} Also, a grazer bit releases its pressure more quickly than a straight-shanked bit when the reins pressure is relaxed. Of course, a tight curb strap reduces the signal of any leverage bit.

Gag bits (Figs 3.8 & 3.9)

In the basic gag bridle, the reins and the cheekpieces of the headstall are one continuous unit.^{6,9,25} When the reins are pulled, the mouthpiece slides upwards in the horse's mouth and transfers much of the pressure from the tongue and bars to the lips and poll. A gag bit, when used properly, provides a rider more control than a standard snaffle without proportionally providing more punishment to the horse's tongue and bars.^{6,8}

It might be thought that the gag functions to lower the head because tension on the reins places pressure on the

poll. But head carriage is more a factor of where the horse finds relief from bit pressure. Since the horse's mouth is much more sensitive to pressure than his poll, if the gag is used with no auxiliary aids, its net effect is to accentuate the basic head-raising action of a snaffle bit.⁸ If strong rein pressure is applied to a gag bridle, the bit is pulled relatively far caudally and can severely punish the horse's tongue, lips and cheeks (Fig. 3.9).

Full bridle

The full bridle or double bridle (Fig. 3.10) has two sets of cheek pieces and two sets of reins. One set is attached to a curb bit; other set is attached to a snaffle bit. The snaffle, which is generally relatively small, is called a bridoon or bradoon and is placed above and behind the curb.^{22,26}

The double bridle with its combination of bits, employing a number of forces to achieve its ends, is an extremely sensitive instrument. When used by a skilled rider on a schooled

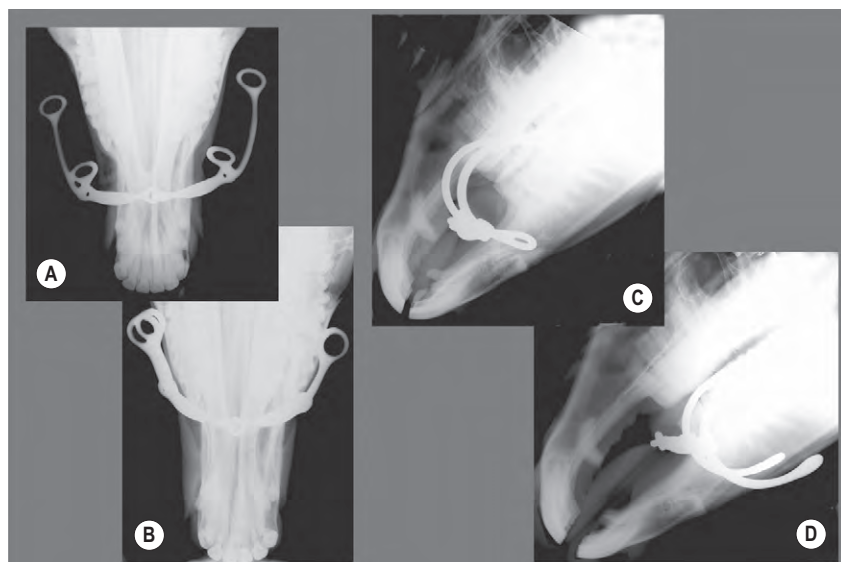


Fig. 3.9 Radiographs of gag bits. (A) Ventrodorsal with no rein pressure. (B) Ventrodorsal under rein pressure. (C) Lateral with no rein pressure. (D) Lateral under rein pressure.



Fig. 3.10 (A) Full bridle on dressage horse. (B) Full bridle on English pleasure horse. (Inset) The snaffle and curb bits on a dressage bridle.

horse, it can place the head with greater finesse than is possible with any other bridle in current use. But the rider needs a considerable amount of skill for this bridle to be effective and humane.

It is often stated that, with the double bridle, the rider uses the snaffle bit to raise the head and turn the horse and the curb bit to lower the head and stop the horse. When the double bridle is used properly, however, nearly all commands for head position, moving and stopping are given via the snaffle.²² The role of the curb is the basically passive one of promoting poll flexion, collection and balance.^{8,26} Excessive tension on the curb rein is the most common cause of problems with full bridles.⁸

The use of the double bridle when the horse is not sufficiently schooled or the rider is not sufficiently skilled can damage the horse's psyche as well as his mouth. The double bridle puts a lot of hardware in the horse's mouth (Fig. 3.11), and the chances of injury are arguably doubled as compared to bridles with a single bit.

Pelhams (Figs 3.12 & 3.13)

A Pelham bit is basically an attempt to gain the advantages of a double bridle with only a single bit in the horse's mouth. The Pelham bit is really just a curb bit with an extra set of rings at the level of the mouthpiece to which an extra set of reins is attached. Tension on the lower rein gives the effect of a curb bit and tension on the upper rein gives the effect of a snaffle bit.

Pelham bits come in a wide variety of forms (Fig. 3.12). The mouthpiece may be straight, curved, jointed, or ported. The shanks may be long or short, fixed or loose. Some have very short shanks and thick rubber mouthpieces and are very mild. Others have ports and long shanks and are more severe. One type, the Kimberwicke (Figs 3.12C & 3.13B), uses only one rein with the hand position, or rein setting, determining whether the bit functions as a snaffle or as a curb.

Critics of Pelhams say that both reins come into play at the same time and confuse a horse. Certainly

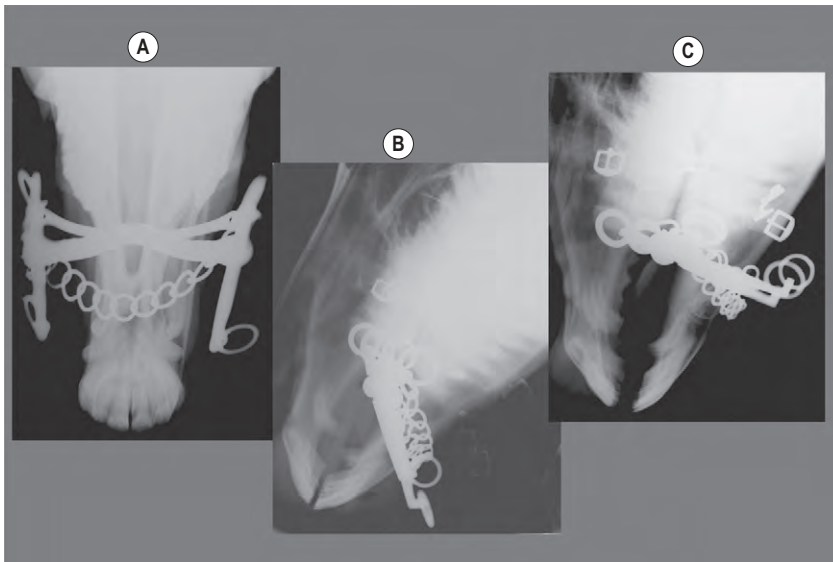


Fig. 3.11 Radiographs of bits on full bridles. (A) Ventrodorsal. (B) Lateral without rein pressure. (C) Lateral under rein pressure.

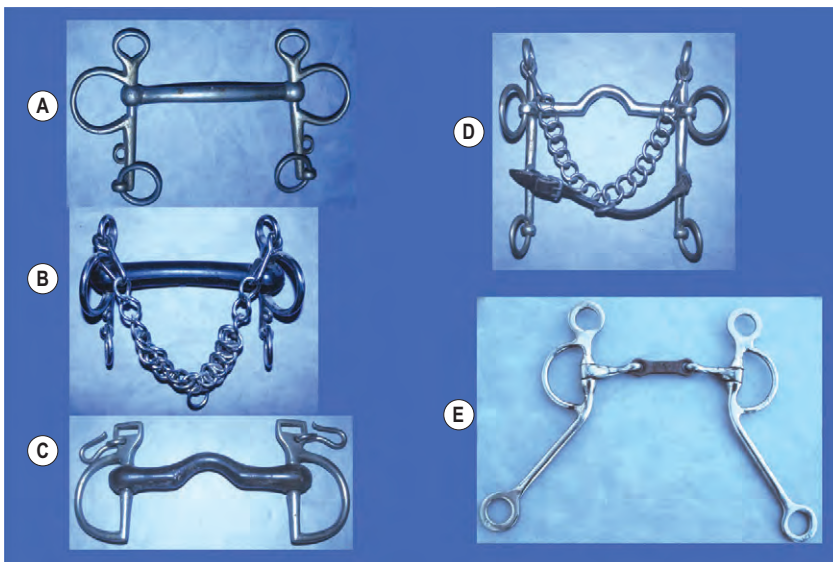


Fig. 3.12 Examples of Pelham bits. (A) Mullen mouthpiece with moderate shanks. (B) Rubber covered mouthpiece with short shanks. (C) Kimberwicke with ported mouthpiece. (D) Long shanked bit with lip strap. (E) Western Pelham with center link, loose cheeks, and long shanks.

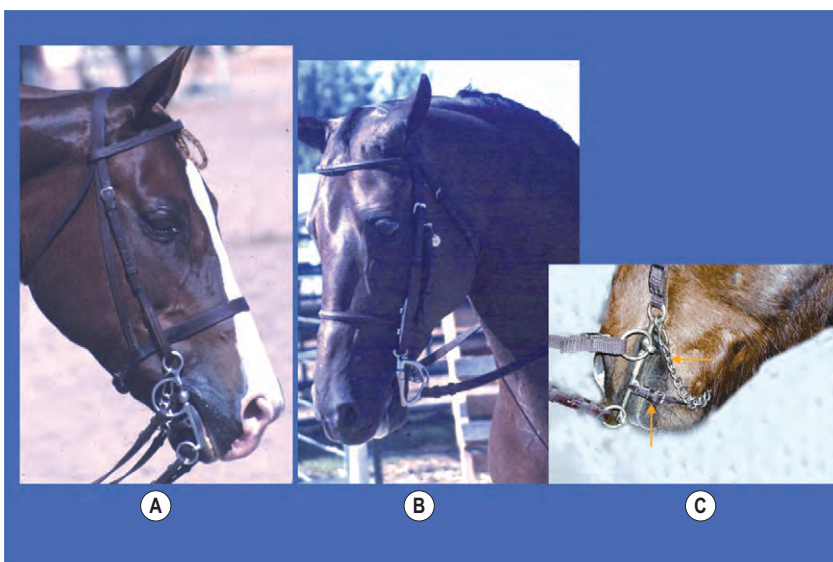


Fig. 3.13 (A) Standard Pelham. (B) Kimberwicke with rein set to lower level in Uxeter cheeks. (C) Proper adjustment of curb chain (upper arrow) and lip strap (lower arrow).

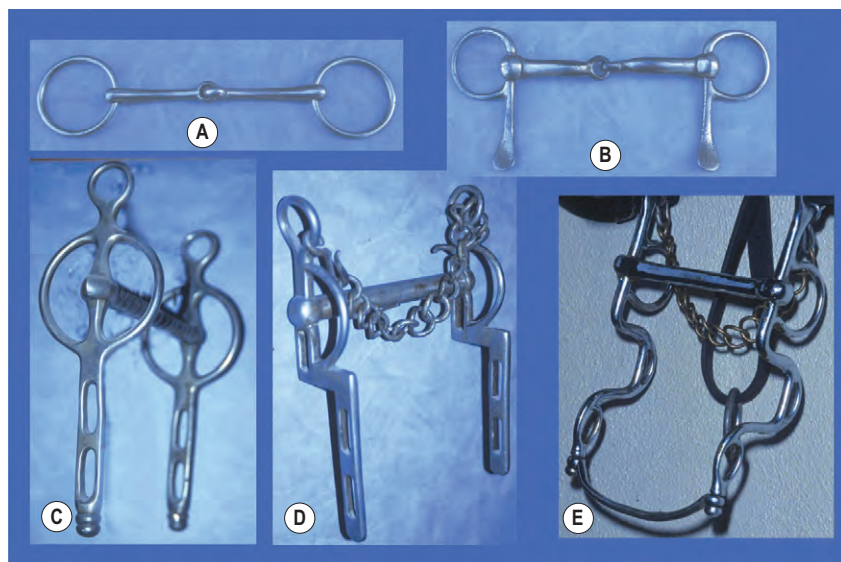


Fig. 3.14 Driving bits. (A) O ring snaffle. (B) Half cheek snaffle. (C) Liverpool. (D) Ashleigh Elbow. (E) Buxton.

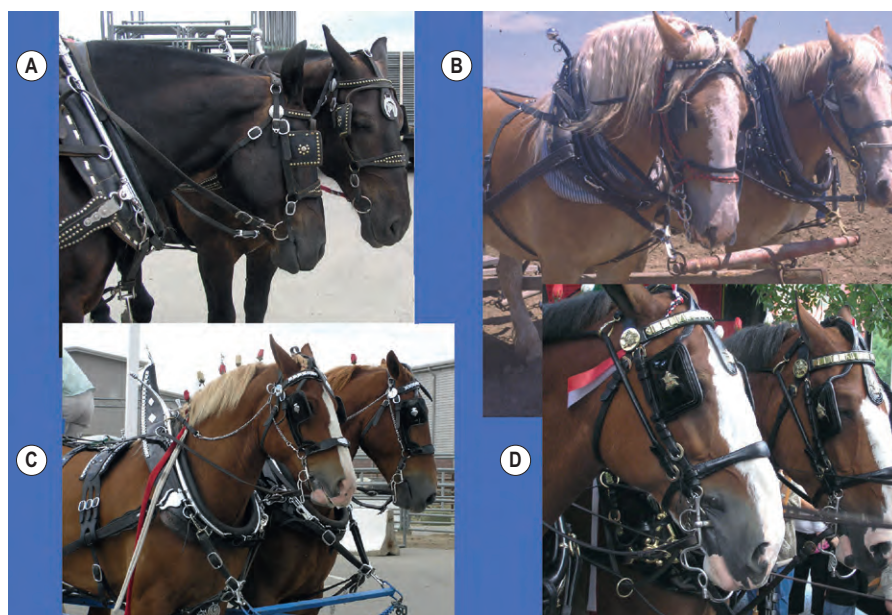


Fig. 3.15 Teams with common driving bits (A) O-ring Snaffle. (B) Liverpool: the line on the horse on the left is attached to the snaffle ring. The line on the horse on the right is attached to the lowest curb ring for greater control. (C) Ashleigh Elbow. (D) Buxton.

the Pelham does not work well in a horse with very long narrow jaws or an exceptionally long interdental space. In such a horse, it is essentially impossible simultaneously to have the curb chain in the chin groove and the mouthpiece in its proper position against the lip corners. The curb chain, under such circumstances, tends to pull backwards until it is beneath the branches of the mandible, and pressure on these is quite painful to the horse and may result in severe bruising. The use of a lip strap (Figs 3.12D & 3.13C) can help to counteract this disadvantage.

Despite all of the criticisms, some horses perform better in the Pelham bit than in any other. In the horse with short jaws and a relatively small interdental space, the single mouthpiece of the Pelham may fit better than the double mouthpiece of the full bridle.

Driving bits (Figs 3.14 & 3.15)

In riding horses, we have stressed the importance of 'getting off of the horse's mouth.' In other words, the rider should cue the horse first with his legs and seat and only secondarily via the bit. However, disregarding the relatively minor role of the whip, the driving horse receives non-verbal communication only through the reins (harness horses) or lines (draft horse) and the bit. Communication with the driving horse is further complicated by the fact that, although the distance between the bit and a rider's hands is seldom more than 30 inches, the distance between the bits of a horse or a pair of horses in harness and a driver's hands is approximately 12 feet.^{1,27} The remoteness of contact is increased to 24 feet or more when horses are driven in tandems or larger teams.^{1,3,22,27,28}

Driving bits for racing trotters and pacers are essentially always snaffle bits with solid or, more commonly, jointed mouthpieces. Such bits are often used on other types of driving horses as well. Driving snaffles often have half cheeks to provide extra lateral control.¹

The Liverpool, Ashleigh Elbow, and Buxton (Figs 3.14 & 3.15) are curb bits commonly used for driving. The mouthpieces of these bits are most commonly straight with a smooth and a corrugated side. However, these bits are also available with a variety of ported and jointed mouthpieces. The reins are attached to rings at the level of the mouthpiece or to one of the two or three slots which are progressively lower in the shanks – the lower the attachment, the more severe the curb action. With the reins at the top position (i.e., through the ring at the level of the mouthpiece), the curb chain does not operate and the effect is that of a plain bar (unjointed) snaffle.¹ All three bits commonly have swiveling (loose) cheeks that can be adjusted so that either the smooth (Fig. 3.14E) or the corrugated side (Fig. 3.14D) of the straight bar mouthpiece is in contact with the horse's tongue and bars.^{1,24}

The Liverpool bit has cheeks that form complete rings around the ends of its mouthpiece with straight flat bars projecting below them (Figs 3.14C & 3.15B). Because it is symmetrical, the cheeks of a Liverpool bit need not be loose to allow the use of either the smooth or corrugated side of the mouthpiece. It is probably the most widely used driving bit.³

The shanks of the Ashleigh Elbow bit (sometimes referred to as the military bit) extend backward at right angles to the cheeks before extending straight vertically (Figs 3.14D & 3.15C).²⁵ This rearward placement of the shanks prevents a horse from seizing them with his lips. Perhaps more importantly, the angle of the shanks alters the balance of the bit making the elbow bit more forgiving, i.e., requiring more pull on the reins to exert pressure in the mouth and releasing pressure more quickly when the reins are slackened, than the straight-shanked Liverpool bit.¹

The Buxton bit (Figs 3.14E and 3.15D), with its S-shaped shanks, prevents a horse from seizing the shanks, but its

balance is closer to that of the Liverpool bit than to that of the Ashleigh Elbow bit. The Buxton is a large, ornate bit that is used for most ceremonial and formal occasions throughout the world.^{1,3,25} The horses in many of the fancy, multiple horse hitches used for advertising or for parades are driven in Buxton bits.

Overchecks and sidechecks (Figs 3.16–3.19)

For most driving horses, a single overcheck rein or two sidecheck reins are added to the bridle to prevent the horse from lowering his head. The overcheck rein runs from the back pad of the harness up between the horse's ears, passes down the front of the horse's face and divides into two straps which fasten to either side of a separate overcheck bit that presses upwards in the horse's mouth (Fig. 3.17). Less commonly, the straps attach directly to the driving bit or to a chin strap.¹

The sidecheck is a variation on the overcheck in which two check reins, rather than joining and running over the top of the horse's head, run through loops on either side of the bridle and back along the sides of his neck to come together at his withers (Fig. 3.18). The practice of some drivers of attaching check reins directly to a leverage driving bit is not recommended, because such an arrangement pulls the bit uncomfortably up into the corners of the horse's mouth and interferes with curb action and driver contact.^{1,3}

Most draft horse bridles are set up with either an overcheck or a sidecheck to prevent the horse from lowering his head to graze or rub and to keep his head in the optimal position for pulling. A check rein is nearly always required for light horses shown in pleasure driving classes or in fine harness classes. Harness racing horses wear overchecks because their heads must be held in an exact position to keep them balanced and on their gait.^{1,23}

The plain overcheck bit (Figs 3.16G, 3.17A & 3.19A) is a very small straight bar bit. However, there are many other types, varying widely in severity (Fig. 3.16). Some racing overchecks, like the McKerron (Figs 3.16A & 3.17B), Crit

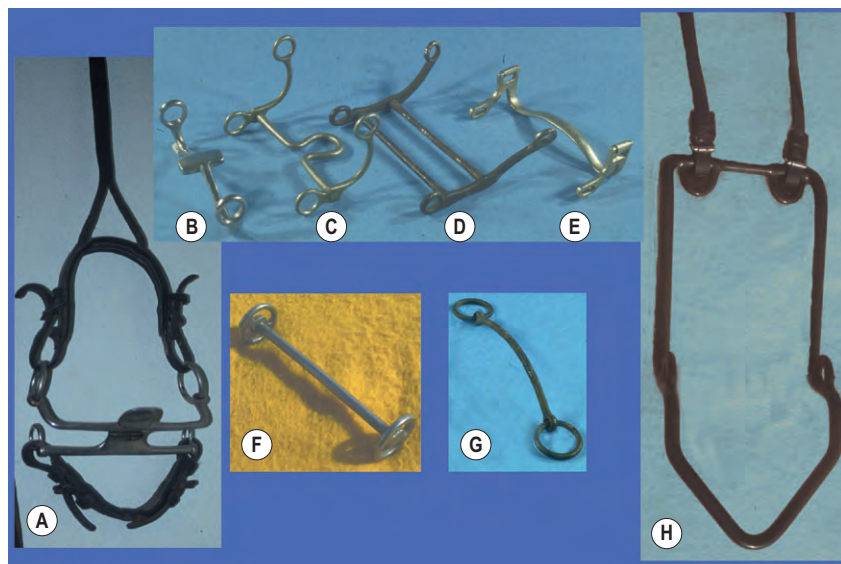


Fig. 3.16 Overcheck bits. (A) McKerron with check rein and nose strap. (B) Burch. (C) Crit Davis. (D) Crabb. (E) Hutton. (F) Speedway. (G) Plain. (H) O'Mara leverage.

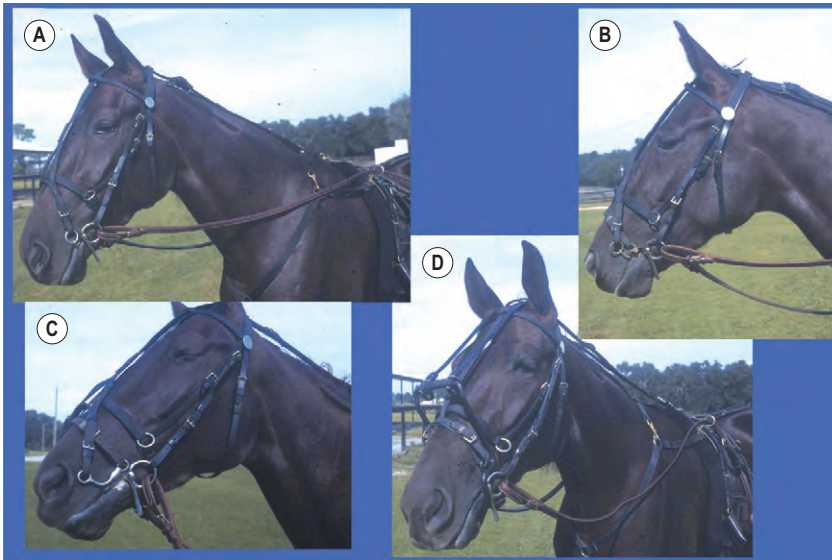


Fig. 3.17 Four overcheck systems used on racing Standardbreds. (A) Plain overcheck bit. (B) McKerron overcheck bit. (C) Crit Davis overcheck bit. (D) O'Mara leverage overcheck. All four driving bits are half-cheek snaffles.

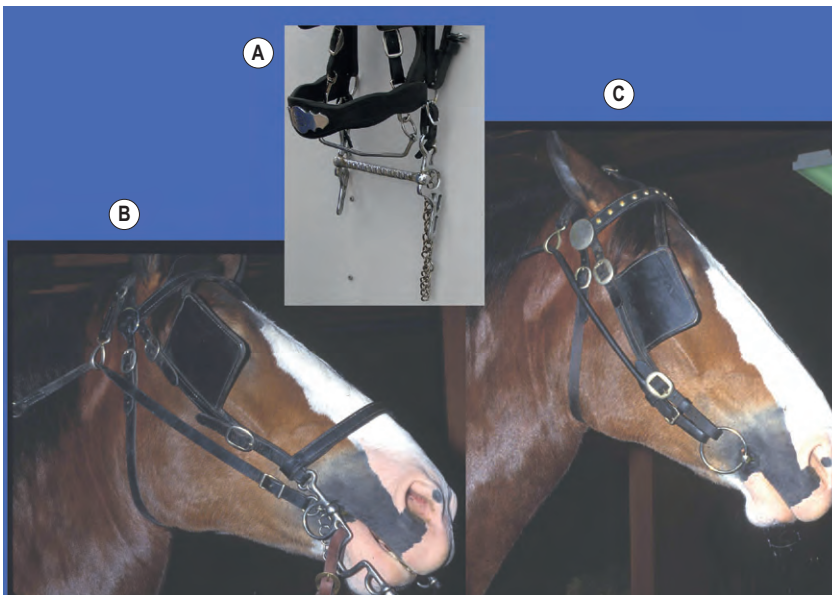


Fig. 3.18 (A) Driving bridle with Ashleigh Elbow and sidecheck bits. (B) Horse bridled with Buxton and sidecheck bits. (C) Sidecheck rein attached to O ring snaffle driving bit.

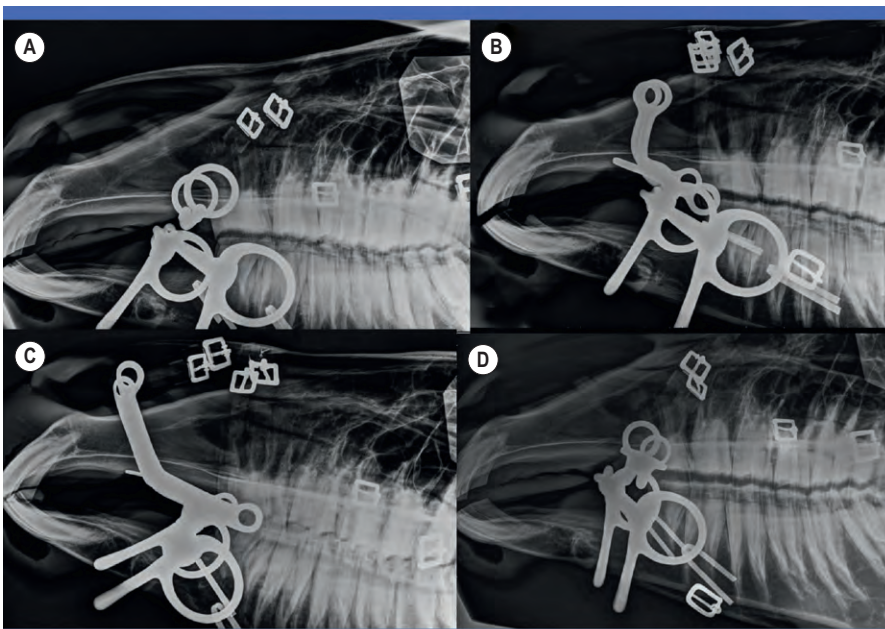


Fig. 3.19 Lateral radiographs of overcheck bits in horses' mouths. (A) Plain overcheck bit. (B) Crit Davis overcheck bit. (C) Crabb overcheck bit. (D) Burch overcheck bit. All four driving bits are half-cheek snaffles.



Fig. 3.20 A mule team prior to hitching to show the coupling lines (arrows) and driving lines (D) from the front and rear. The coupling lines attach to the inside rings of the bits, cross each other, pass through rings on the harness of the opposite horse's collar and buckle into the driving lines (D). When the team is hitched and traveling straight ahead, the coupling and driving lines join over the mules' backs.

Davis (Figs 3.16C, 3.17C & 3.19B), and Crabb (Figs 3.16D & 3.19C), listed in increasing order of severity, are used in combination with nose straps to prevent horses from leaning into their check reins.^{1,29} Potentially even more severe is the Burch overcheck (Figs 3.16B & 3.19D), which is shaped so as to press directly into the hard palate.

The cumbersome appearing, but reasonably humane and effective, Raymond and O'Mara (the so-called leverage overchecks) involve no bit at all. (Figs 3.16H & 3.17D) When a horse leans into a leverage overcheck, a strap over his face presses down onto his nose and the U- or V-shaped lower portion of the overcheck lifts up on his chin.^{1,29}

The combination of forces applied by the driving and check reins can place marked stress on a horse's mouth, and one must be aware of the type of overcheck used when caring for a horse's teeth and mouth. For example, the hard palate should be examined carefully for injury in a harness-racing horse who performs poorly when checked with a McKerron, Hutton, Burch, Crit Davis, or Crabb bit. If the palate is sore, one should consider recommending a change to a chin chain or leverage overcheck.¹

Removal of wolf teeth, careful floating and rounding of the upper premolars and removing sharp edges from upper canine teeth are of special importance whenever overchecks are used.^{1,30} The upper canines are placed more caudally than the lower canines thus providing less space for the overcheck bit than for the driving bit. The overcheck bit may be forced backwards, especially if the horse's head is checked very high, pinching the gums against the teeth. Even leverage overchecks can force a horse's cheeks against upper points or caps.

Team driving

The previously mentioned remoteness of control in driving horses is compounded in the case of a pair or larger team, in which each horse is controlled by a draft line (rein) and

a coupling or stub line^{1,3,22,27,28} (Fig. 3.20). The draft and coupling lines are connected so that only one left line and one right line for each pair of horses finally reaches the driver's hand.^{1,3,22} In a team of two horses the draft line of each horse extends from the driver's hand to the outside ring of the horse's bit. The coupling line of each horse is attached to his draft line as it passes over the horse's back, passes through a ring at his withers and crosses over to the inside ring of the bit of the opposite horse^{3,27,28} (Fig. 3.20). Thus, when the left line is pulled, both horses turn left, and when the right line is pulled, both horses turn right. This provision is a practical necessity to make accurate line handling possible, but it does not allow constant even contact to be maintained with each horse's mouth.^{1,3}

The exact adjustment of the coupling lines, which may be buckled at varying distances along the draft or outside line, is a critical factor in team driving in assuring that both horses are moving with their heads held straight to the front.^{3,28} The coupling lines must both be adjusted at the same time, because when only one line is adjusted, the other will pull one horse's head to one side or the other.^{22,28} Moving coupling lines further forward on the draft line spreads the team apart, and moving the coupling lines back brings the team closer together.²⁸

Proper alignment of the horses in a team is critical for correct bit function. If one horse is ahead of the other, or if the horses are too far apart or too close together, the bit will be off-center in one or both horses' mouths.²⁸ Sores at the corners of the lips of one or both horses may be a clue that the alignment of the horses is improper.¹ Fortunately, to prevent the chafing or injury that would otherwise occur, horses tend to place their heads so as to center the bits in their mouths.^{1,28} However, this compensation results in one or both horses' heads being turned to one side, making straight traveling and turning difficult.²⁸

If one horse is ahead of the other and thus pulling more than his share of the load, his bit should be made more severe, while that of his partner should be made less severe

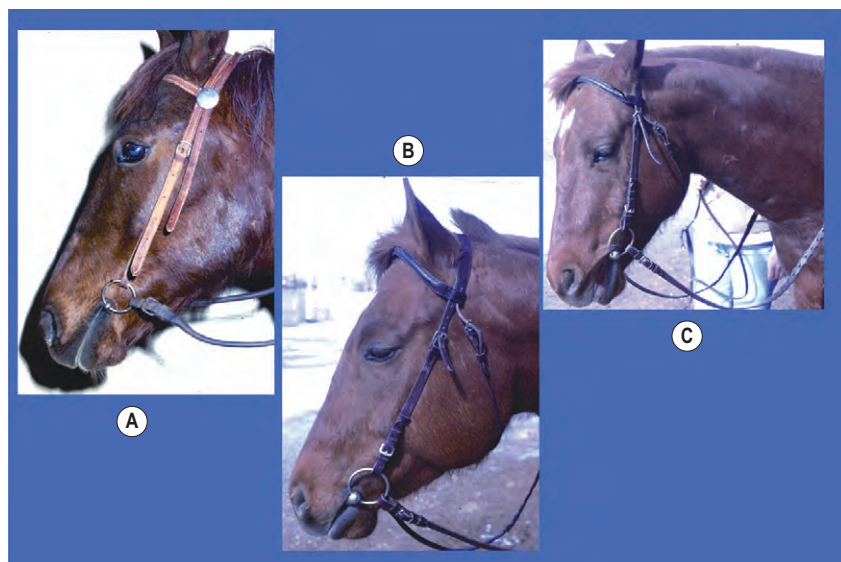


Fig. 3.21 (A) Bridles are often adjusted so that the bit causes a wrinkle at the commissures of the lips. (B) Bridle adjusted so that bit hangs loosely. (C) Bridle adjusted too tight.

(Fig. 3.15B).^{1,28} The different slots for attachment of the lines to Liverpool, Ashleigh Elbow, and Buxton bits are ideal for the quick changes in bit pressure that sometimes become necessary in the middle of an event.

Fitting the bit

The variation in size, shape, and degree of sensitivity of horses' mouths should be considered when selecting and fitting bits and bridles.^{9,17,18} The width of the mouthpiece should accommodate the width of the mouth. If the mouthpiece is too short, it will pinch the corners of the lips against the cheek teeth. Too long, and the bit can shift sideways, sawing on the lips, tongue and bars. An oversized mouthpiece also puts the port or joint out of position and makes the bit ineffective and possibly painful. Ideally the mouthpiece should not project more than $\frac{1}{2}$ inch or less than $\frac{1}{4}$ inch beyond the corners of the lips on either side.⁸

The position where the bit fits in the bar space is also important. However, this adjustment varies from horse to horse and bit to bit. A popular rule-of-thumb for adjusting snaffles has been to adjust the bit so that the commissures of the horse's lips are pulled into one or two wrinkles (Fig. 3.21A). The problem with such a fit is that releasing the pressure on the reins gives the horse no relief at the corners of his mouth.^{6,8,9} A better method is to first hang the bit relatively loosely until the horse learns to pick it up and carry it and then adjust the headstall to position the bit where the horse has determined it is most comfortable (Fig. 3.21B). A driving horse's bit should rest squarely against the corners of the mouth without wrinkling them.¹

A horse with a short or shallow mouth (from lips to corners) carries the bit forward in his mouth where his tongue rides highest. A horse with a deep mouth holds the bit farther back in his mouth where his tongue sits lower in his jaw space and his palate is more concave.⁹ Consequently, there is less space between the tongue and hard palate in the shallow-mouthed horse and, everything else being equal, he requires a bit with a thinner mouthpiece and a port

providing more tongue relief than the bit required by the deeper-mouthed horse.

An older horse may have less space for a bit in his mouth. As a horse ages, his incisors slope further forward while the cheek teeth wear down, causing the palate to sink closer to the tongue. A bit that was comfortable for a horse when he was 5 may no longer be comfortable when he is 20.

One must consider more than the external dimensions of a horse's head and his age in choosing an appropriate bit. The size and shape of a horse's oral cavity often correlate poorly with the size and shape of its head, its age or its sex.¹⁷ In selecting and properly fitting a bit, there is no substitute for careful manual and digital examination of a horse's mouth. Periodic reexaminations are indicated because wearing of the teeth, or even dentistry, can change the shape of the oral cavity.¹⁷

Bitless bridles

Some horses that don't respond well to a bit perform quite well with bitless bridles. Bitless bridles can be especially useful in preventing mouth injuries caused by the overzealous hands of a beginning rider or in allowing a mouth injury to heal.^{13,31}

When choosing bitless headgear, horse owners should consider the same factors that they would when choosing any other bridle. Otherwise, they risk dulling the horse's sensitivity and responsiveness to rein signals.¹³

Traditional hackamore (Fig. 3.22A)

The hackamore provides a means of promoting poll flexion, collection, and balance along with optimal stopping power and directional control while staying out of the horse's mouth. It is used with a light bumping action, initiated by gently tugging on one rein at a time. Alternating pulls and releases can be used to ask the horse to flex at the poll and stop.³²

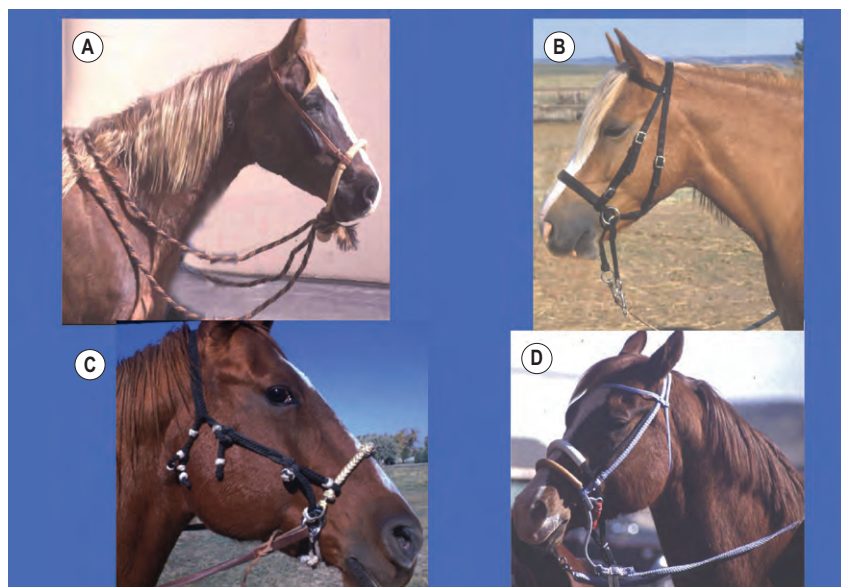


Fig. 3.22 Bitless bridles. (A) Traditional bosal hackamore. (B) Cross-under bitless bridle. (C) Side pull. (D) Mechanical hackamore.

The heart of the hackamore is the bosal, a braided rawhide or leather noseband that is fashioned around a rawhide core. An 18- to 22-foot hair rope, the mecate, is wrapped above the heel knot of the bosal to form a continuous rein and lead rope.⁹ Bosals vary greatly in diameter, with the appropriate size depending upon the horse's sensitivity and stage of training. Generally one moves from thicker, heavier bosals to thinner, lighter ones as the hackamore horse progresses.³¹

The bosal should rest on the bridge of the nose, or just slightly above, where it is supported by the nasal bones. When placed too low, it exerts excessive pressure on the horse's nasal cartilages and interferes with his breathing.

Obviously, a hackamore does not damage a horse's tongue and bars, but the bosal contacts some very sensitive points on his face. Rein pressure presses the bosal into the top of the face and into contact with the cheeks and lower jaw all at the same time. Heavy hands on the reins or an ill-fitting bosal can abrade the horse's nose and jaw and press his cheeks against the upper premolars.

Mechanical hackamore (Fig. 3.22D)

While mechanical hackamores are indeed bitless bridles, they function more like curb bits than like true hackamores.^{9,31} Mechanical hackamores have metal shanks that attach to a noseband and curb chain. While there is no mouthpiece, the shanks amplify force to the nose, chin and poll in the same way that a leverage bit works on the mouth, chin and poll. Because of the wide variety of mechanical hackamores, it is possible to vary the severity as required.

Other bitless bridles

The Side Pull (Fig. 3.22C) is little more than a hybrid halter.⁹ Rein rings are placed on each side of the noseband in line with the commissures of the lips. A chin strap beneath the rein rings allows the noseband to be snugged into position. The side pull promotes lateral control with pressure on the reins leading the horse's nose in the desired direction.⁹

The Cross Under Bitless Bridle (Fig. 3.22B) distributes pressure across the poll, behind the ears, down the side of the face, behind the chin and across the nose.³³ The bridle consists of two loops, one located over the poll and the other located over the nose, with both crossing under the horse's chin. The reins run from the rider's hands through two rings on either side of a noseband and then cross beneath the horse's jaw and loop over the poll. With this figure-eight configuration, simultaneous pressure can be applied to the poll, nose, chin, and cheeks. Pressure on one rein pushes the horse's head in the desired direction rather than pulling on its mouth with a bit.^{31,34}

The side pull and the cross-under are gentle bridles that minimize the stress on a horse's mouth and work exceptionally well on some horses.

Accessories

Some biting problems can be alleviated and a horse's performance improved by adding biting accessories, such as nosebands and martingales. We must be familiar with the functions of such accessories in caring for horses' mouths because they alter the function of, or the direction of pull on, the bit.

Nosebands

The simplest noseband, the cavesson, functions merely to stabilize the bridle (Figs 3.10A & B) or as a point of attachment for a martingale (Fig. 3.24A). Other types of nosebands are used to aid or modify the action of the bit.

Drop, flash, and figure-8 nosebands (Figs 3.23A, 3.23B and 3.23C) are used to hold the bit in the proper position and to keep horses from gaping their mouths. The top of the drop noseband is fitted just at the lower end of the nasal bones while the lower portion passes below the bit and lies in the chin groove. A drop noseband is fairly restrictive and can cause problems if not properly adjusted.³⁵ If it is too long on top and too short below, it will hang too close to the



Fig. 3.23 Nose bands. (A) Drop. (B) Flash. (C) Figure-8. (D) Cheeker. (E) Shadow roll.

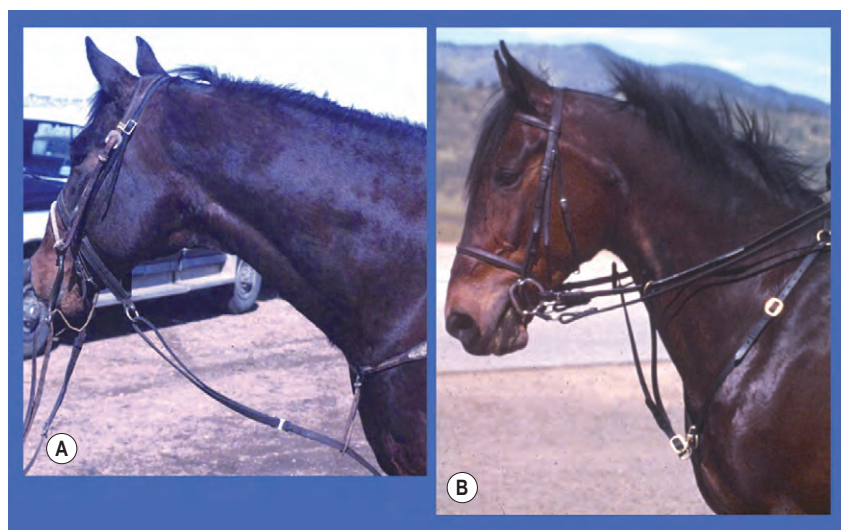


Fig. 3.24 Martingales. (A) Standing. (B) Running.

nostrils, interfering with breathing, and the bottom will press the bit into the corners of the lips and hold the mouth too tightly closed.

The flash noseband attaches to the center of a simple cavesson above the nose. The lower end passes below the bit and lies in the chin groove. The figure-8 or grackle noseband has a top strap that fastens above the bit and a lower strap that fastens under the bit and lies in the chin groove. The two straps intersect in the middle of the face at about the level where a cavesson would be located. Both the flash and the figure-8 nosebands have actions similar to the drop noseband but are less severe and are not as likely to interfere with breathing.³¹

The so-called 'cheeker' (Fig. 3.23D) is not really a noseband but rather is a rubber strap that runs from the crownpiece of the bridle down the middle of the horse's face where it separates to attach on either side of a snaffle bit. Like the drop, flash, and figure-8 nosebands, the cheeker holds the bit up in the horse's mouth.³¹

Sheepskin-covered cavessons or shadow rolls (Fig. 3.23E) are used to prevent a horse from seeing the ground in front of him, and thus to prevent his shying at shadows or other potentially frightening sights. Cheekers and shadow rolls are used mainly on racehorses.

Martingales

There are two basic kinds of martingales: standing (known in western circles as tie-downs) and running (Fig. 3.24). Both types of martingales promote balance and the proper action of a bit by discouraging, or physically preventing, the horse from raising his head too high or extending his nose too far.^{9,31} Both types begin with a strap running from the saddle girth up the front of the horse's chest. The standing martingale, which exerts its pressure on the horse's nose, continues as a single strap that attaches to the bottom of a noseband. The running martingale, which exerts its pressure on the bit, forks

into two straps with rings at their upper ends through which the reins run.

A martingale should not be adjusted so tightly as to pull the horse's head down into an unnatural or uncomfortable position. The martingale should become active only when the horse raises his head, thus preventing him from evading the bit and becoming unbalanced.³¹

Conclusion

The knowledge of anatomy, physiology, pharmacology and nutrition, even when coupled with high levels of diagnostic,

mechanical and surgical skills and the possession of the best equipment available is not always sufficient to provide optimal dental care to horses. One must consider the age, performance discipline, ability, and level of competition of the horse, not to mention the level of skill and the experience of his rider or driver. The more the veterinarian knows about bits, bridles and accessories as they relate to the above factors, the better he can fulfill the needs of his clients and the more rewarding his dentistry practice will be.

References

- Bennett DG. Biting and dentistry for the driving horse. In: Proceedings of the 53rd Annual Meeting of the American Association of Equine Practitioners, 2007; 53: 451–459
- Scoggins RD. Bits, biting and dentistry. In: Proceedings of the 47th Annual Meeting of the American Association of Equine Practitioners, 2001; 47: 138–141
- Coombs T. Bits for harness horses. In: McBane S, ed. The horse and the bit. Howell Book House, New York, 1988, pp 127–131
- Scrutchfield WL. Wolf teeth: how to safely and effectively extract and is it necessary. In: Workbook: American Association of Equine Practitioners Focus on Dentistry 2006, pp 56–60
- Dixon PM, Gerard MP. Oral Cavity and Salivary Glands. In: Auer JA, Stick JA, eds. Equine Surgery, 3rd edn. Elsevier, St Louis, 2006, pp 321–351
- Bennett DG. Bits and biting: form and function. In: Proceedings of the 47th Annual Meeting of the American Association of Equine Practitioners. 2001; 47: 130–137
- Young JR. The schooling of the horse. University of Oklahoma Press, Norman, OK, 1982, pp 235–263
- Bennett DG. An overview of bits and biting. In: Workbook: American Association of Equine Practitioners Focus on Dentistry. 2006, pp 181–195
- Lynch B, Bennett DG. Bits and bridles: power tools for thinking riders. EquiMedia, Austin, 2000
- Johnson TJ. Surgical removal of mandibular periostitis (bone spurs) caused by bit damage. In: Proceedings of the 48th Annual Meeting of the American Association of Equine Practitioners 2002; 48: 458–462
- Smith JC. Osteitis and sequestrum formation of the interdental region of the mandible in 11 polo ponies. Vet Rec 1993; 133: 188–189
- Tremaine WH. Management of Equine Mandibular Injuries. Equine Vet Educ 1998; 10: 146–154
- Hague BA, Honnas CM. Traumatic dental disease and soft tissue injuries of the oral cavity. Vet Clin North Am 1998; 14: 333–347
- Van Lancker S, Van Den Broeck W, Simoens P. Incidence and morphology of bone irregularities of the equine interdental spaces (bars of the mouth). Equine Vet Educ 2007; 19: 103–106
- Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease Part 3: a long-term study of 400 cases: disorders of wear, traumatic damage and idiopathic fractures, tumors and miscellaneous disorders of the cheek teeth. Equine Vet J 2007; 2: 9–18
- Jansson N, Hesselholt M, Falmer-Hanson J. Extirpation of a mandibular canine tooth in a horse as a treatment for severe bit-induced trauma to the bar. Equine Veterinary Education 1980; 10: 143–145
- Engelke E, Gasse H. An anatomical study of the rostral part of the equine oral cavity with respect to position and size of a snaffle bit. Equine Veterinary Education 2003; 15: 158–163
- Engelke E, Gasse H. Position of different snaffle bits inside the equine oral cavity. Pferdeheilkunde 2002; 18(4): 367–376
- Easley J. Dental and oral examination. In: Baker GJ, Easley J, eds. Equine dentistry, 2nd edn. Elsevier, London, 2005, pp 151–169
- Sutton A. The bridle and the bit. In: The injury-free horse. David and Charles, Newton Abbott, 2001, pp 59–60
- Clayton HM, Lee RA. Fluoroscopic study of the position and action of the jointed snaffle bit in the horse's mouth. Journal of Equine Veterinary Science 1984; 4: 193–196
- Edwards EH. The complete book of bits and biting. David and Charles, Newton Abbot, 2000
- Riegle G. Training the pacer. In: Greene C, ed. The new care and training of the trotter and pacer. U. S. Trotting Association, Columbus, OH, 1996, p. 337
- McBane S. The illustrated guide to horse tack. David and Charles, Newton Abbot, 1992, pp 49–91
- Malm GA. Bits and bridles, an encyclopedia. Grasshopper, Valley Falls, 1996
- Crossley A. The double bridle. In: McBane S, ed. The horse and the bit. Howell, New York, 1988, pp 60–78
- Telleen M. The draft horse primer. Rodale Press, Emmaus, PA, 1977, p 256
- Bowers S, Steward M. Farming with horses. MBI, St Paul, 2006
- Haughton T. Choosing the right equipment. In: Greene C, ed. The new care and training of the trotter and pacer. U S Trotting Association, Columbus, 1996, pp 184–214
- Caldwell LA. Canine teeth in the equine patient – the guide to eruption, extraction, reduction and other things you need to know. In: Workbook: American Association of Equine Practitioners Focus on Dentistry. 2006, pp 47–55
- Bennett DG. Biting accessories and bitless bridles. In: Workbook: American Association of Equine Practitioners Focus on Dentistry. 2006, pp 237–242
- Connell E. Hackamore reinsman. Lennoche, Katy, TX, 1952
- Cook WR. Pathophysiology of bit control in the horse. J Equine Vet Sci 1999; 19: 196–204
- Cook R. Tradition and status quo, or science and advance? Vet Times 2007; 37: 16–18
- Loriston-Clarke J. The Complete Guide to Dressage. Courage Books, Philadelphia, 1987, pp 130–131

The business of equine dentistry

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Customers are the most important visitors on our premises. They are not dependent on us. We are dependent on them. They are not an interruption in our work. They are the purpose of it. They are not an outsider in our business. They are part of it. We are not doing them a favor by serving them. They are doing us a favor by giving us an opportunity to do so.

Mahatma Gandhi

Horse owners expect dental care to be high quality and delivered with expertise. Enthusiasm is a crucial component of high quality veterinary service. Delivering exceptional levels of dental care with enthusiasm creates a positive atmosphere, making a dental procedure a satisfying experience for both the owner and practitioner. The client's needs are fulfilled, and the client develops trust in the practitioner, which is a cornerstone of a successful dental practice. Enthusiasm is often the key ingredient that separates a successful equine dental practice from a practice that is less successful.

Dentistry has become an important sub-discipline of veterinary practice. In the recent past, equine dentistry was a discipline overlooked by many veterinarians, perhaps because the economic value of the horses used for agricultural work was low. When horses became valued because of emotional attachment or because of their worth as a sport horse, their economic value increased, and dental care became more important to owners. Many of today's clients compete in various kinds of sporting events for horses, and the horse's interaction with the bit and bridle is a critical part of the interaction between horse and rider during these events. Clients recognize that equine dentistry is essential in maintaining a good interaction between the horse and bit. When a practice is not willing to provide high-quality equine dental care, clients seek dental care elsewhere. In many parts of the world, horses are still used in agriculture, and for these horses, dental maintenance is vital for their overall health and welfare.

As drugs for sedation, instrument design and dental techniques have improved, the activity in equine dentistry at modern veterinary practices has increased markedly. Dentistry can easily comprise 10–15% and sometimes up to 30% of the total workload and revenue produced in a

general equine veterinary practice. To perform this much dentistry effectively, a veterinarian must incorporate an appropriate business model into the practice.

Major contributing business factors

Three major factors are required for a business model to function, and a deficit in any of the three decreases the likelihood of success.

- Structures: the availability of necessary physical and human resources.
- Processes: the use of efficient resources.
- Systems: the provision of useful information to management so that business decisions can be made.

Structures

Expertise develops a trusting relationship

Equine dentistry is the one common service that the entire spectrum of equine clients need throughout all four seasons of the year. This type of service, when expertly offered, can become the cornerstone of a stable's herd health program. If the veterinarian is able to expertly perform an oral examination and provide for the horse's dental needs efficiently and competently, the owner is satisfied. After a relationship of mutual trust between the veterinarian and client is established, the client is likely to accept the advice of the veterinarian in other matters of health. During these discussions, dental care strategies for various age groups of horses can be outlined, and the importance of dentistry for the performance and long-term well-being of the horses can be illustrated. When the managers or owners realize how important dental care is for their horses, they become ardent supporters of a herd health strategy scheduled around dental appointments.

It is incumbent upon veterinary graduates to receive extra instruction and to develop skills in the practice of equine dentistry to achieve an acceptable level of judgment and competence in this discipline. Dental procedures must be performed in a competent, efficient manner that is safe for the patient, practitioner, and handler. Like surgery, the practice of equine dentistry requires skill, knowledge, and experience.



Fig. 4.1 Creative signs direct clients to your business and publicize various types of services.

Advanced educational programs are readily available for veterinarians seeking to improve their knowledge about equine dentistry and their skills in performing dental procedures. Practitioners must continue to educate themselves to stay current in this rapidly developing discipline. Continuing education in dentistry has never been more accessible. Many organizations and institutions provide avenues for equine dental education taught by leaders in the profession. Interested veterinarians can enroll in module courses to learn more about current techniques in diagnosis of dental diseases and treatment of affected horses. In addition, seminars provide a venue for practitioners interested in improving their knowledge about equine dentistry to meet veterinarians providing high quality dental services who are willing to share their knowledge. Applying knowledge obtained by attending courses dealing with equine dentistry promotes business for a practice.

Total practice commitment

A totally committed staff sends a message to clients that equine dentistry is a priority of the practice. 'Visual effects' around the office, clinic, or ambulatory vehicle create a distinctive corporate image (Figs 4.1 & 4.2). Dental posters, audiovisual aids, anatomical specimens, and dental logos on clothing, caps, stationery, and pens provide a special image and a positive atmosphere for the practice.

When equine dentistry becomes a focus for a practice, a dental procedure is no longer just a procedure to 'fit in' between vaccinations and the next emergency. To maintain this focus, ample time must be allotted for dental procedures, so that the procedures are performed to a high standard.



Fig. 4.2 Clinic logos and signage on practice vehicles to promote services offered are ideal methods of advertising. (Contributed by Christopher Pearce MRCVS.)

The practice team must collectively agree on the level of service to provide and then devise strategies to deliver these levels of service. Dental education and services provided to clients in a pleasant and courteous manner, with enthusiasm and skill, produce referrals given confidently by satisfied clients, and these referrals promote the growth of the practice.

Referral of complex cases

A practice does not have to provide all levels of equine dental care, but members of the practice should have a good knowledge of current standards of dental care. They should be able to accurately diagnose dental problems and if necessary, be willing to refer a horse with a complex dental condition to a more experienced veterinarian. Clients are satisfied if a proper presumptive diagnosis is made and a referral to a veterinarian competent to resolve the condition is provided. They become dissatisfied if they receive an inaccurate diagnosis or feel that ample effort was not provided to resolve the dental condition.

Health management

The health needs of the entire horse should be addressed because comprehensive dental care involves much more than just floating teeth. A dental examination should include a cursory general physical examination before a sedative/analgesic is administered. Queries from the owner about the horse's nutritional and prophylactic health needs, reproductive health, training strategies, and behavioral problems can be answered during the examination. The 'value-added' service builds the owner's trust and confidence in the veterinarian.

Equipment

When developing a dental specialty within a practice, basic sets of instruments are required to diagnose dental conditions and perform routine dental procedures. Equipment needed to conduct an ambulatory dental practice may differ from that needed in a hospital, and may depend on climatic conditions and the type of infrastructure available at farms and stables. The cost of equipment required to perform basic, good quality dentistry is within the budget of most practices.

As caseload and economic rewards increase, individuals within the practice may develop interests in sub-specialties of dentistry. As individuals develop expertise in advanced dental procedures, investment in more education and additional dental equipment becomes economical. Much of the equipment and instrumentation can be purchased in stages, and selecting equipment to purchase is an important part of business planning. New equipment needed during the growth phase of a dental practice might include exodontic and endodontic instrumentation, restraint devices, imaging modalities, medical record systems, and technical assistance.

Processes

From the client's perspective, there are four Cs to good veterinary care:

- Client solution: does the service meet the client's needs?
- Cost: is the economic and emotional justification better than that of other competitors?
- Convenience: is the service easily accessible and convenient?
- Communication: did the veterinarian provide adequate information?

Client awareness (seeing is believing)

In our fast-moving society, giving customers what they expect is no longer enough. To gain an edge on competitors, a practice must help clients learn what they need.¹ To do this, a practice should integrate marketing into other activities.

Each veterinarian in the practice can increase the client's awareness of the importance (i.e., the need) of dental care by incorporating an oral examination into other routine, physical examinations, such as a lameness examination. Incorporating an oral examination into other examinations adds to the client's knowledge of the status of their horse's health.

Many clients, including experienced horse owners, have never viewed the inside of a horse's mouth, and when they can see the dentition, they begin to appreciate the horse's need for regular dental care. Many horse owners are shocked to see buccal lacerations and large hooks. Seeing is believing, and from that moment on, horse owners understand the importance of dental care.

Cost of service

The value of dental services is determined by the quality of service delivered, the skill of the person delivering the service, the regional cost of living, and business costs. One method of determining a fee schedule for dental services is to consult with local practices to determine what the average charges for the dental services are in the area. Fees for dental procedures can also be compared to fees charged for similar types of veterinary procedures or to fees charged by other equine businesses, such as farrier work. After these guidelines are determined, the practice can calculate expenses required to deliver dental services, and based on these expenses, a fee that produces a suitable profit can be generated.

Convenience

Efficient and convenient delivery of dental services should always be a goal. In some jurisdictions, supervised, licensed, veterinary technicians can assist in providing some aspects of dental care. Using technical personnel to assist with dental procedures, charting medical records, caring for equipment, educating clients, immunizations, and invoicing can greatly increase the efficiency of a practitioner. Clients value a task completed in a timely fashion because it allows them to plan their own day. Clients who have horses that are not easily transported appreciate the convenience of having dental procedures performed on their premises. For others, transporting their horse to a facility that has all the amenities may be more attractive.


Client communication

Mailed notices and electronic mail are important modes of communication to remind clients that their horse is due for physical and dental examinations. Educational brochures for clients can be custom-designed or purchased through veterinary organizations, such as the American Association of Equine Practitioners. Clients appreciate a reminder because scheduling an examination becomes one less thing they have to remember, and the reminder shows that the practice cares about their horse's well-being. By organizing 'dental days' at various venues, a practice can make dental care more economical and convenient for clients. Information notices can be tailored to clients' needs based on their horse's age, occupation, or location. Reminders allow a practice to schedule dental procedures months in advance, and this assists management in planning growth of the practice. Scheduling permits work to be distributed evenly throughout the day and among members of the practice.

Absentee clients

The portion of the equine population that is under the care of trainers, and not the owner, presents a special challenge to the veterinarian.² The owner, trainer, and veterinarian are all members of a business relationship, and good rapport between all members, especially between the veterinarian and the trainer, is fundamental to the success of this relationship. If the owner must receive medical information about his or her horse directly from the veterinarian, the trainer must also receive the same information so that the trainer does not feel threatened.

On site, cellular communication with an absent owner is convenient and effective, but the billing statement is the best means of documenting to the owner the health care that his or her horse has received. A billing statement can be used as an opportunity to send the owner a medical record of each horse, along with an additional statement that details the charges for each horse and the total payment that is due. A well-designed billing statement/dental record becomes an advertisement for the practice because it can be used to illustrate the veterinarian's expertise (Fig. 4.3). Clients appreciate receiving this dental record and share the information contained within it with other horse owners. The dental record should be easy for an owner to understand, it should accurately describe findings of the dental examination, and it should outline procedures done to correct dental abnormalities. The invoice and dental record can be generated at



Equine Dental Chart

**Bell Equine Veterinary Clinic, Butchers Lane, Mereworth,
Maidstone, Kent, ME18 5GS. Tel. 01622 813700**

Clinician: _____

Owner/Trainer: _____ Date: _____

Address: _____ Horse: _____

Breed: _____

Age: _____ Sex: _____

Location: _____

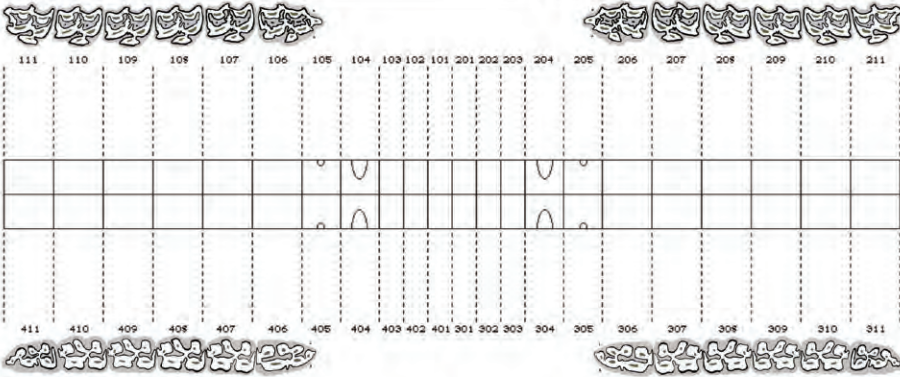
Tel. _____

Referring Vet/EDT: _____

Problems: _____

Tetanus status: _____ Sedation: _____

Lateral Excursion: Before _____ After _____



Soft Tissues

Arcade#1 _____

Arcade#2 _____

Arcade#3 _____

Arcade#4 _____

Key:

SP(B/L) - Sharp points (buc./ling.)	P/E - Partially erupted
CH - Caudal hook (S/M/L)	U/E - Unerupted
RH - Rostral hook	CAL - Calculus
St - Step	X - Extracted
Wa - Wave	DT/r - Deciduous tooth/ root sliver
WC - Worn crown	SN - Supernumary tooth
TC - Tall crown	BU - Buccal ulceration
ROT(B/L) - Rotated (buc./ling.)	LU - Lingual ulceration
# - Fracture	PD - Periodontal pocket
O - Missing tooth	Dias - Diastema

TMJ: _____ Occlusal Angle: Left _____ Right _____

Body Condition: OW VG G AV P VP

Further notes:

Please make your next appointment in _____ months for a dental checkup.

Signed: _____

Fig. 4.3 A dental record form can be a valuable aid in communicating with the owner/trainer. The form should clearly show what dental problems the horse has, what treatments were given and when the next follow-up visit is scheduled. (Contributed by Rob Pascoe BVSc MRCVS.)

the time of service using a laptop computer, which greatly improves efficiency, and collections, and decreases mistakes in the billing process.

Grouping with scheduled procedures

Opportunities can be found to schedule dental procedures by auditing common veterinary procedures that clients

request throughout the year. Procedures such as blood testing for equine infectious anemia, annual vaccinations, insurance examinations, reproductive work, and preparation for competitions, can be scheduled with dental work. All horses involved in competition need regular dental care, and the office staff can use the computer to predict when this regular dental care can be provided to a group of clients.

Table 4.1 Number of dental cases that practices treated in the year 2004 (among only those practices who said they provide dental services) (AAEP Poll of 2005 Concerning Dentistry)

31 %	More than 200 dental cases
21 %	101–200 dental cases
21 %	51–100 dental cases
17 %	26–50 dental cases
10 %	1–25 dental cases
1 %	No dental cases

Systems

Well-organized offices with state-of-the-art information systems report on the resources and processes of the business. The record-keeping system for inventory, invoicing, payroll, medical records, statistics, and research generates reports that allow the managing veterinarian to determine how well the business plan is functioning. Accounting statements from these records also give valuable information that can be used to plan business strategies. Information systems can also identify potential areas for growth in dentistry. Software tools can be used to monitor client and veterinary activity. A high number of dental procedures performed by some members of the practice can be identified as a goal for others in the practice (Table 4.1).

Numbers of various types of veterinary procedures can also be compared with numbers of dental procedures. For example, horses being tested for equine infectious anemia or immunized so that they can attend an equestrian event are likely to also need dental care (Table 4.2). Many areas of

Table 4.2 Practices polled by the authors

Percentage of dentistry to practice's total gross income	7.78 %
Percentage of dentistry to equine infectious anemia tests	81.0 %
Percentage of dentistry to influenza and rhinopneumonitis vaccine	51.0 %

practice activity can be quantified to allow comparisons with the overall amount of dental work performed.

Often, more dental care could be performed but the practice lacks the personnel to perform it. The information system can predict if hiring a new associate and purchasing new instrumentation to fill the void are economically feasible. Because the cost of basic dental instrumentation is moderate, compared with equipment needed for other subspecialties, deciding whether or not to expand equine dentistry within the practice is usually easy.

Summary

Veterinarians with an interest in equine dentistry have the opportunity to make dentistry a significant part of their practice. The practitioner who is enthusiastic can acquire the requisite knowledge and skills to efficiently and effectively perform dentistry. With the advent of sedative/analgesia agents and motorized instrumentation, equine dental practice is no longer laborious, and anyone who has interest in equine dentistry can include it in his or her practice. Veterinarians who become competent in equine dentistry find it to be one of the most rewarding and interesting aspects of equine veterinary practice.

References

1. Kotler P. Marketing management. Pearson Education, New Jersey 2000, p 21
2. Mitchell JS. Absentee owner communication: an equine practitioner's challenge. Equine Veterinary Education 2007; 19(4): 111

Dental anatomy

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Introduction

Equine dental nomenclature

Adult mammals have four types of teeth, termed **incisors**, **canines**, **premolars (PM)** and **molars (M)**, in a rostrocaudal order.¹ Teeth embedded in the incisive (premaxillary) bone are by definition termed incisors. The most rostral teeth in the maxillary bone are the canines. In horses, the main three premolars have evolved to become more complex and morphologically identical to the molars (i.e., molarization of premolars) to facilitate grinding of foodstuffs. Consequently, in horses, premolars 2–4 (Triadan 06–08) and the three molars (Triadan 09–11) can be collectively termed cheek teeth. Each type of tooth has certain morphological characteristics and specific functions. Incisor teeth are specialized for the prehension and cutting of food, and the canine teeth are for defence and offence (for capture of prey in carnivores). Equine cheek teeth function as grinders for mastication. The **occlusal** or masticatory surface is the area of tooth in contact with the opposing teeth; the term **coronal** refers to the crown. The **anatomical crown** is that part of the tooth covered by enamel and in brachydont (short crowned) teeth, such as in humans, is usually the same as the **clinical (erupted) crown**, i.e., the erupted part of the tooth. However, in equine teeth (hypsodont – long crowned), especially young teeth, most of the crown is unerupted and is termed unerupted or **reserve crown**, and a smaller proportion (circa 10–15% in young adult horses) of crown is clinical crown. The term occlusal ('coronal' is a much less satisfactory term for hypsodont teeth) is used when referring to direction towards the occlusal surface. The reserve crown can be subdivided into **alveolar crown** (i.e., that part lying in the alveolus) and the **gingival crown**, i.e., that part which has erupted from the alveolus, but which is still lying sub-gingivally.²

Apical refers to the area of tooth furthest away from the occlusal surface, i.e., the area where the roots later develop and is the opposite of occlusal. **Lingual** refers to the medial aspect (area closest to the tongue) of all the lower teeth, whilst **palatal** refers to the same aspect of the upper cheek teeth. **Buccal** (aspect closest to cheeks) refers to the lateral aspect of both upper and lower (cheek) teeth, whilst **labial** refers to the rostral and rostrolateral aspect of teeth (incisors and canines only in horses) close to lips. The terms

interproximal or **interdental** refer to the area of teeth that face the adjoining teeth in the same arcade (incisors) or row (cheek teeth). The terms **mesial** and **distal**, which refer, respectively, to the surfaces of teeth that face towards and away from an imaginary line between the central incisors, are satisfactory for equine incisors – that form a true arch. However, these terms are unsatisfactory for the equine cheek teeth, because they do not form part of a continuous dental arch as they are separated from the incisors by the 'interdental space' ('physiological diastema', 'bars of mouth'). The term **cheek teeth row** is a more appropriate term to describe the straight rows of six cheek teeth.

Equine dental evolution

The evolution of equine dentition is comprehensively covered in Chapter 1, and the functional consequences of this dental evolution are discussed in Chapter 6; nevertheless, some salient anatomical aspects of the differentiation of brachydont into hypsodont teeth are briefly discussed here. Following ingestion of their coarse forage diet, the necessary grinding down of this foodstuff to a small particle size (the average length of fibers in equine feces is just 3.7 mm)³ to allow more efficient endogenous and microbial digestion, causes a high degree of wear on their cheek teeth. However, unlike ruminants that can later regurgitate their food to allow further mastication, horses have only one opportunity to effectively grind their foodstuffs.

Brachydont teeth (permanent dentition) fully erupt prior to maturity and are normally long and hard enough to survive for the life of the individual because they are not subjected to the prolonged and high levels of dietary **abrasive** forces that herbivore teeth must contend with. In contrast, hypsodont teeth slowly erupt over **most** of the horse's life at a rate of 2–3 mm/year,^{4,5} which is similar to the rate of **attrition** (wear) on the occlusal surface of the tooth, provided that the horse is on a grass (or some alternative fibrous diet, e.g., hay or silage) rather than being fed high levels of concentrate food. The latter type of diet reduces the rate of occlusal wear and also restricts the range of lateral chewing actions⁶ and thus dental overgrowths can occur. Both brachydont and hypsodont teeth have a limited growth period (although this period is very prolonged in the latter group)

and thus are termed **anelodont** teeth. A further evolutionary progression to cope with highly abrasive diets, as has occurred in some rodents such as rabbits (and some extinct equid lineages), is the presence of teeth that continually **grow** throughout **all** of the animal's life, that are termed **elodont** teeth.

Many brachydont teeth have a distinct neck between the crown and root, a feature that could not be present in permanent hypsodont teeth that have a prolonged eruption period. At eruption, hypsodont teeth have no true roots and in this text the term root specifically refers to the apical area which is enamel free.^{7,8} The formation of roots in equine teeth permits further dental **growth** for some year or so after these teeth erupt, in addition to the very prolonged eruption of these teeth for most of the horse's life. The terms apical or periapical are much more appropriate to describe this area of equine teeth that, for example, commonly develop apical infections of the mandibular 07s and 08s (2nd and 3rd cheek teeth) even prior to the development of any roots. About 25 % of equine mandibular cheek teeth still have no root development even 12 months following eruption.⁹

Because of the marked physiological wear (**attrition**) on the surface of hypsodont teeth, exposure on the occlusal surface of enamel ridges, and also of dentin and cement (cementum) is inevitable and leads to the presence of alternate layers of these three calcified dental tissues on the occlusal surface. This is in contrast to the sole presence of enamel on the occlusal surface of brachydont teeth. The presence of infolding of the peripheral enamel, and also of enamel cup-like infoldings (infundibula) in the upper cheek teeth and all incisors also increases the amount and irregularity of exposed enamel ridges on the occlusal surface. This peripheral enamel infolding is greater in mandibular cheek teeth to compensate for the lack of enamel infundibulae that are present in the maxillary cheek teeth.¹⁰ This feature confers additional advantages to hypsodont teeth, as the different calcified tissues wear at different rates (enamel slowest, dentin and cementum fastest) and therefore a permanently irregular occlusal surface that is advantageous in the grinding of coarse fibrous foodstuffs is created by a self-sharpening mechanism.

Embryology of teeth

Dental development (dentogenesis) involves several sequential processes, including epithelial-mesenchymal interaction, growth, remodeling and calcification of tissues until a tooth is fully developed.^{11,12,13} During dental development, the tooth germ undergoes a series of distinct, consecutive events termed the initiating, morphogenetic and cytodifferentiative phases. These phases occur in all types of mammalian dentition;¹⁴ however, their timing and termination vary, i.e., compared to brachydont teeth, hypsodont teeth have a delayed termination of the morphogenetic and cytodifferentiative stages (at their apical region), whilst in elodont teeth (such as in some rodents), these stages continue throughout all of the animal's life. Tooth formation begins by the development of a horseshoe-shaped, epithelial thickening along the lateral margin of the fetal oral cavity. This epithelial thickening (termed the primary epithelial band) invaginates into

the underlying mesenchymal tissue to form two distinct ridges, the vestibular lamina, and (caudal to it) the dental lamina. The dental lamina produces a series of epithelial swellings called **tooth buds** along its buccal margin. This stage is known as the **bud stage** of tooth development (Fig. 5.1). At this stage, a mesenchymal cell proliferation develops beneath the hollow ectodermal tooth buds and invaginates into these tooth buds, which then develops into inverted cap-shaped structures called the **enamel organs**. This is termed the **cap stage** of dental development (Fig. 5.1).

All deciduous teeth and the permanent molars develop from the enamel organ of the dental laminae. However, permanent incisors, permanent canines, and permanent premolars are formed from separate enamel organs that are derived from lingual (medial) extensions of the dental laminae of the deciduous teeth (Fig. 5.1). Consequently, the deciduous incisors are normally displaced labially (towards the lips) by the erupting permanent incisors.

After formation of the enamel organ, the mesenchymal cells continue to proliferate within the concave aspect of the enamel organ, and are then termed the **dental papilla**, a structure that is later responsible for dentin and pulp formation. These cells now also extend peripherally, as a structure termed the **dental sac** (follicle), which surrounds and protects the enamel organ and dental papilla until tooth eruption occurs (Fig. 5.2).^{1,15} The enamel organ, dental papilla and dental sac are together termed the **tooth germ**, with each germ responsible for an individual tooth.

The enamel organ proliferates further, and in brachydont teeth now assumes a concave, bell-like shape, which is termed the **bell stage** of dental development. At this stage, the concavity of the enamel organ increases, while the mesenchymal cells of the dental papilla invaginate further into its hollow aspect (Fig. 5.1). Additionally, in some equine teeth (all incisors and maxillary cheek teeth), invaginations of enamel epithelium that will later become infundibula develop from the convex aspect of the 'bell' into the papilla (one per incisor and two per upper cheek teeth). Equine cheek teeth have multiple cusps (raised occlusal areas) that arise from protrusions on the convex aspect of the bell. The enamel organ in equine incisors and in all brachydont teeth is circular on transverse section; however, the enamel organ of equine cheek teeth (which are rectangular to square on transverse section) develops peripheral infoldings¹⁶ that later produce the infolded peripheral enamel.

Most cytodifferentiative events in the tooth germs occur during the transitional period between the cap and bell stages. The ectodermal cells lining the concave aspect of the enamel organ become the **internal enamel epithelium**, and the cells lining the convex aspect of the enamel organ form the **external enamel epithelium**.¹² Between them lies a third layer containing star-shaped cells with large intracellular spaces, termed the **stellate reticulum** (Fig. 5.1), which has nutritive and mechanical functions in enamel development. The cells of the internal dental epithelium develop into tall columnar cells with large, proximally located nuclei. This development induces alterations at the molecular level in the underlying dental papilla whose uppermost cells now rapidly enlarge, becoming odontoblasts. The first layer of dentin is now laid down along the basal membrane, which then disintegrates. These events reciprocally induce the

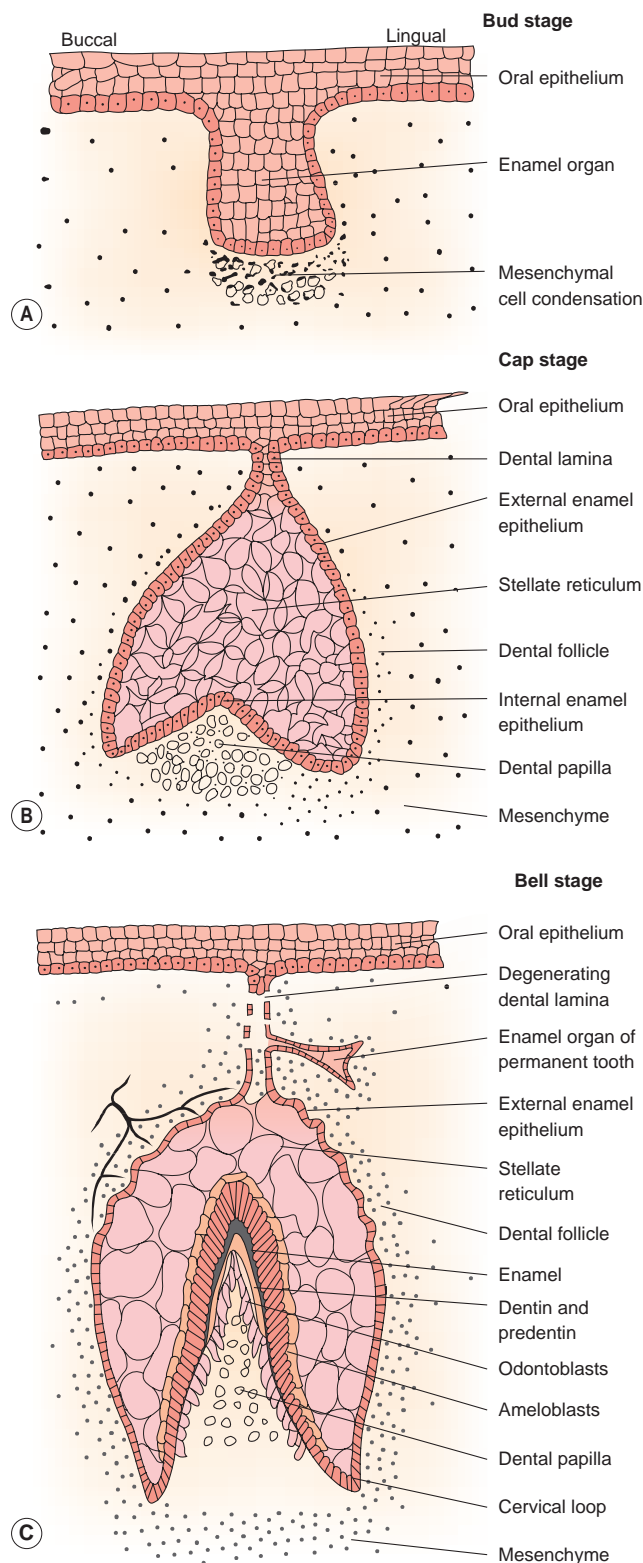


Fig. 5.1 The three early stages of development of a brachydont or hypsodont tooth. (Reproduced from Kilic⁷² with permission.)

overlying internal enamel epithelial cells to differentiate into ameloblasts which now begin to produce enamel.¹⁷

The ameloblasts initially deposit a structureless enamel layer and then migrate away from the enamel-dentinal interface, and form a projection termed **Tome's process** at their

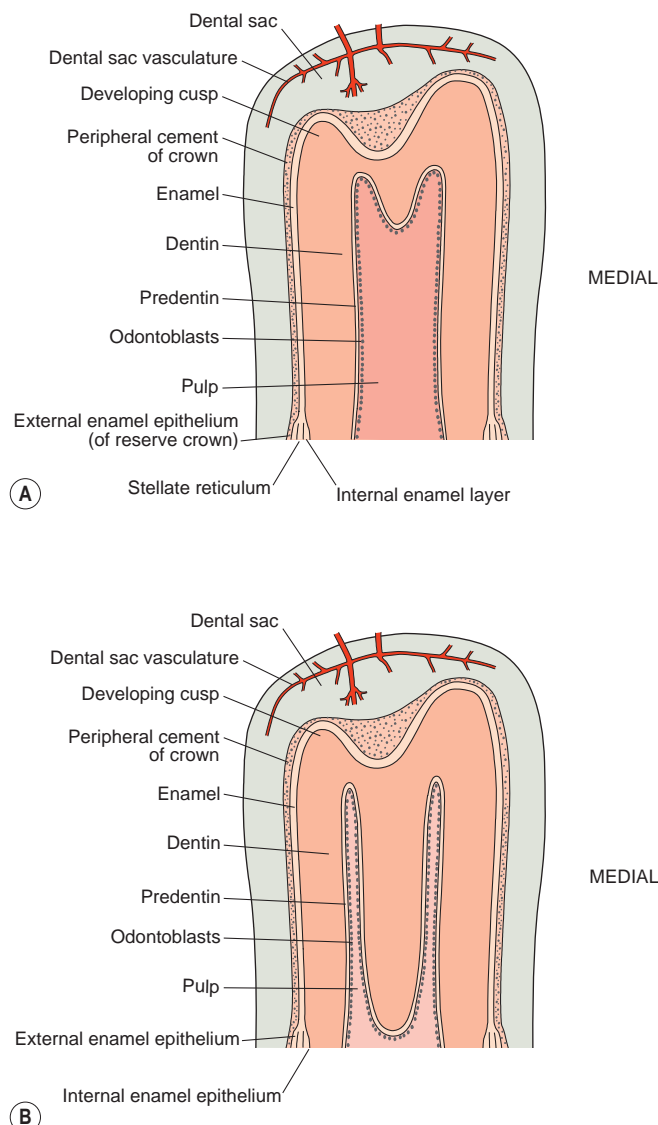


Fig. 5.2 Two stages of the development of a multicusped hypsodont tooth without an infundibulum (i.e., a lower cheek tooth) showing the presence of coronal cement and enamel that are covered by the dental sac. The large common pulp chamber (A) later develops separate pulp horns (B) due to deposition of dentin by the odontoblasts within the common pulp chamber.

distal aspect. Secretions from the proximal aspect of Tome's process form interprismatic enamel, and secretions from the surface of Tome's process form the enamel prisms. The development of enamel and dentin (and later, also of cement) occurs in two consecutive phases, the secretion of extra cellular matrix of mucopolysaccharides and organic fibers, which is then followed by its mineralization.^{18,19}

Odontoblasts, like ameloblasts and cementoblasts (that produce cement), are end cells, meaning that they cannot further differentiate into other cell types. During dentin deposition, the basal aspects of odontoblasts gradually become thinner and form long fine cytoplasmic extensions termed **odontoblast processes**, that remain within the dental tubule, whilst the odontoblast cell body gradually moves centrally on the peripheral of the pulp horn, remaining on the surface of the developing dentin.¹³

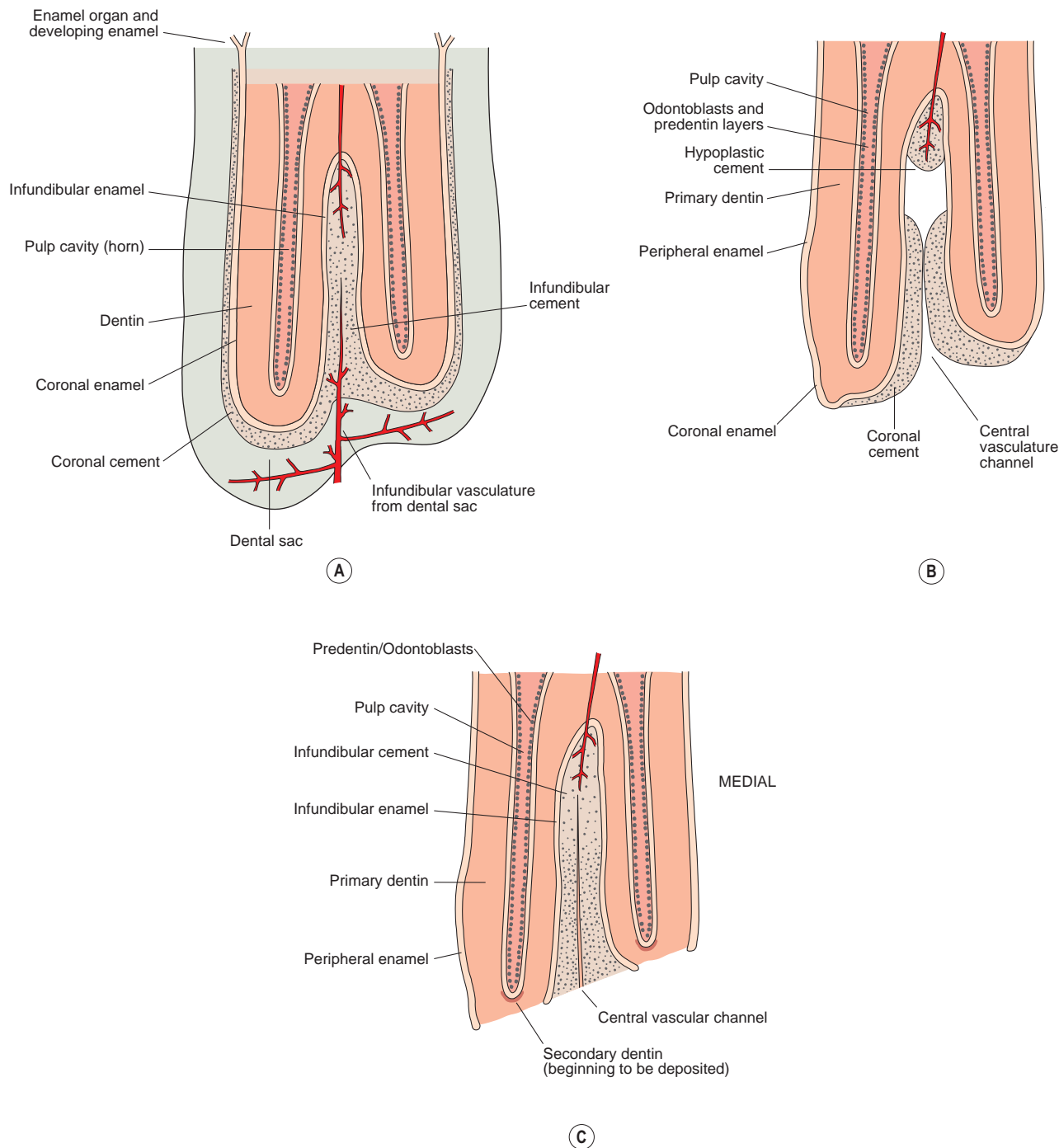


Fig. 5.3 The crown and occlusal surface of a multicusped hypsodont tooth with an infundibulum (i.e., an upper cheek tooth) (a) immediately prior to eruption (b) immediately following eruption, showing loss of the dental sac over the occlusal surface and (c) following wear of the primary occlusal surface to expose the secondary occlusal surface which is the permanent occlusal surface in hypsodont teeth. Note the additional apical blood supply to the infundibulum.

In multi-cusped teeth (such as equine cheek teeth) mineralization begins independently at each cusp tip (Figs 5.2 & 5.3) and then merges, as calcification progresses down towards the amelodentinal (enamel-dentin) junction.¹ As dentin and enamel deposition continues, odontoblasts and ameloblasts move in opposite directions and thus avoid becoming entrapped in their own secretions. Radiography has shown the calcification of equine deciduous cheek teeth

buds (three in each quadrant) to be underway by the 120th day of fetal life and to be completed by 240 days.²⁰ The deciduous 06 (PM2) germs are largest, indicating that they develop first. Calcification of the first permanent tooth bud (09s) begins about 6 months later.²⁰

In brachydont teeth, vascularization begins at the periphery of the tooth germs at the early cap stage, and blood vessels then grow into the dental sac and dental papilla.¹³

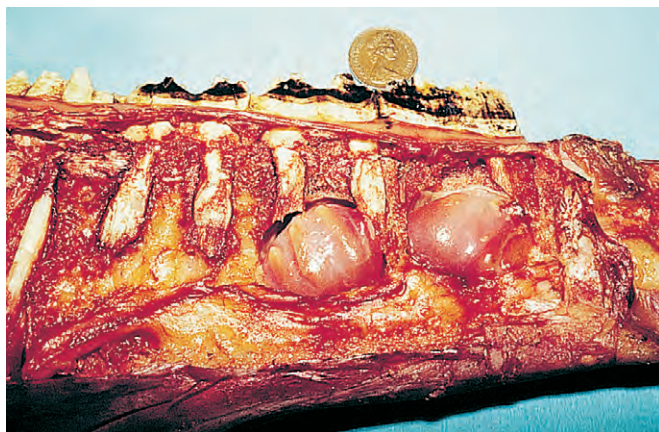


Fig. 5.4 Dissected hemimandible of a yearling Thoroughbred showing the tooth germs of the permanent 06 and 07 mandibular cheek teeth developing beneath and causing resorption of their overlying temporary counterparts. Some calcified developing cusps can be seen on the developing teeth through the semi-transparent dental sac. Note the resorption of the apices of the overlying deciduous teeth by the developing permanent teeth.

Until this stage, the enamel epithelium is supplied by small mesenchymal capillaries. Once dentinal and enamel mineralization begins, the connection between the enamel epithelium and the dental papilla is completely lost. The developing enamel is now solely nourished by the vasculature of the surrounding dental sac (Figs 5.3 & 5.4).

After crown formation is completed in brachydont teeth, the external and internal enamel epithelial cells at the cervical region proliferate down over the dental papilla as a double layer of cells that (at this site) is termed *Hertwig's epithelial root sheath* (Fig. 5.2). This epithelium induces the underlying mesenchymal cells to differentiate into odontoblasts, which produce dentin.¹³ With the progressive distal disintegration of Hertwig's epithelial root sheath, the dental sac cells come into direct contact with dentin. Interaction between these two tissues now induces the cells of the dental sac (mesenchymal cells) to convert into cementoblasts and then to lay down cement (cementum).^{11,15} In equine teeth cement deposition occurs over the entire crown, including over the future occlusal surface just prior to eruption¹⁶ (Fig. 5.3). When the equine tooth has reached its full length, the epithelial root sheath disintegrates, and no further enamel can be formed.

In the infundibula (two in all upper cheek teeth and one in all incisors), cement deposition proceeds by cementoblasts, that are nourished by vasculature from the dental sac (Fig. 5.3) and also via openings in the apical aspects of the infundibula.²¹ Immediately after eruption (or following loss of the overlying deciduous tooth), the soft tissue of the dental sac is quickly destroyed by mastication and consequently infundibular cement no longer has any occlusal blood supply (Fig. 5.3). The cement at the occlusal aspect of the infundibulum can now be regarded as an inert or 'dead' tissue, but cement deposition can continue more apically, possibly for some years if an apical infundibular blood supply is present. Because of the frequent absence of complete filling of more central areas of the cheek teeth infundibula, the term *central infundibular cemental hypoplasia* has been

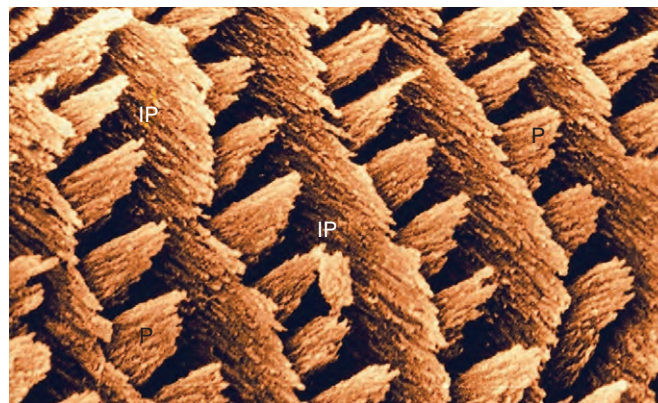


Fig. 5.5 Scanning electron micrograph of Equine Type-1 enamel. This shows parallel rows of enamel prisms (P) lying on flat plates of interprismatic enamel (IP). The enamel crystals within the enamel prisms are oriented parallel to the long axes of the prisms while the enamel crystals of the interprismatic enamel plates are oriented at right angles to the prisms (x3860).

advocated for this feature²² as discussed further in the cementum section.

Dental structures

Enamel

Enamel is the hardest and most dense substance in the body. Due to its high (96–98%) mineral content, it is almost translucent, and gains its color from that of the underlying dentin. Being ectodermal in origin, much of its limited organic component is composed of the keratin family of proteins, in contrast to the largely collagenous proteins of dentin and cement (i.e., connective tissue – reflecting their mesodermal origin). In equine teeth, enamel (except on the occlusal surface) is usually covered by dull, chalk-like peripheral cement. However, at the rostral aspect of the incisors, and more occlusally on the cheek teeth, this peripheral cement is usually worn away, thus exposing the shiny underlying enamel. The deciduous incisors often have little overlying cementum and thus appear whiter and shinier than their permanent successors. Enamel, with its high mineral content and absence of cellular inclusions (unlike dentin or cement) can be regarded as almost an inert or 'dead' tissue. Therefore, as the ameloblasts die off once the tooth is fully formed, enamel has no ability to repair itself. Enamel is almost fully composed of impure hydroxyapatite crystals (Fig. 5.5) which are larger than the hydroxyapatite crystals of dentin, cement, or bone. Enamel hydroxyapatite crystals are arranged both into structured prisms which may be contained in a prism sheath, and also into less structured, interprismatic enamel. Different species, different teeth within a species and even different areas of teeth in an individual can have differently shaped enamel prisms or different arrangements of prismatic and interprismatic enamel, which form the basis for enamel classification in equidae.²³

Equine enamel is composed of two main types termed Equine Types-1 and -2 enamel, with smaller amounts of a third enamel, i.e., Equine Type-3 enamel sometimes

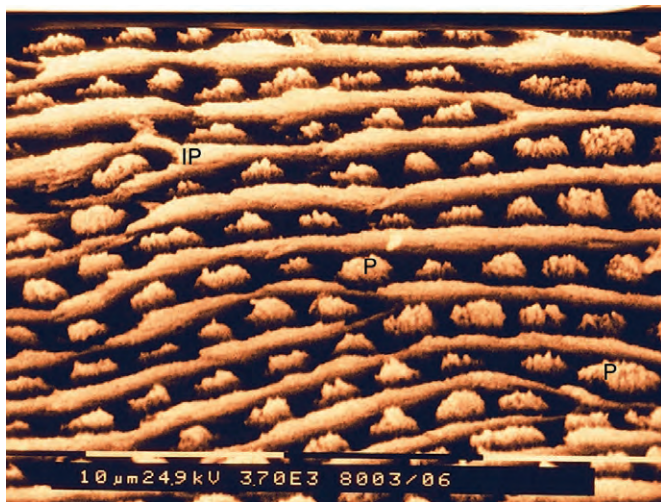


Fig. 5.6 Scanning electron micrograph of Equine Type-1 enamel showing interprismatic plates (IP) alternating with rows of prisms (P). Note the convergence and branching of some of the interprismatic enamel plates (x3700).

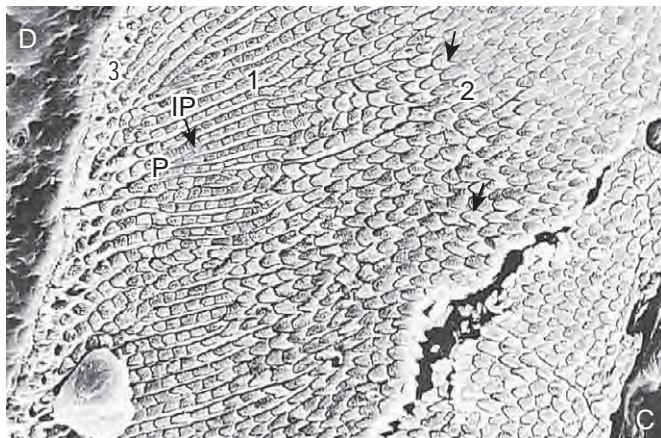


Fig. 5.7 Scanning electron micrograph of a section of an equine tooth showing dentin (D) enamel and cement (C). A thin layer of Equine Type-3 enamel (3) is visible on the left at the amelodentinal junction. Adjacent to this area is a wider layer of Equine Type-1 enamel (1) showing interprismatic enamel (IP) that is contiguous with Type-3 enamel and enamel prisms (P). To the right is a wider layer of Equine Type-2 enamel (2) that in this area has horseshoe-shaped prisms (↑) (x482). (Reproduced from Kilic et al²³ courtesy of the Editor of *Equine Veterinary Journal*.)

detected.²³ Equine Type-1 enamel is present on the medial aspect of the enamel folds, i.e., at the amelodentinal junction. It is composed of prisms that are rounded or oval on cross section and lie in parallel rows between flat plates of dense interprismatic enamel (Figs 5.5 & 5.6). Equine Type-2 enamel is present on the periphery of the enamel layer, i.e., at the amelocemental (enamel to cement) junction, and is composed solely of enamel prisms ranging from horseshoe to keyhole in shape (Fig. 5.7) with no interprismatic enamel present. Equine Type-3 enamel is composed of prisms completely surrounded by large quantities of interprismatic enamel in a honeycomb-like structure and is inconsistently present as a thin layer at both the amelodentinal and amelocemental junctions (Fig. 5.7).

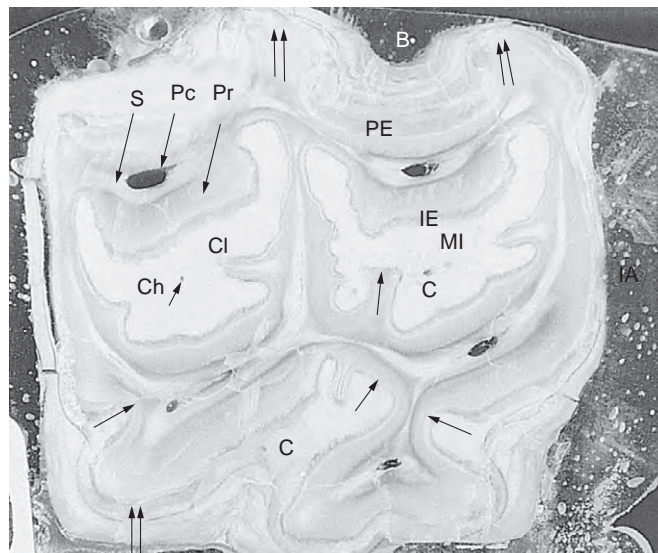


Fig. 5.8 Transverse subocclusal section of a methyl methacrylate embedded upper 09 of an 18-year-old horse. The rostral (mesial) infundibulum (MI) and the caudal (distal) infundibulum (CI) are surrounded by infundibular enamel (IE), and the infundibular cement has a central channel (Ch). Five pulp cavities (Pc) are present and are surrounded by areas of secondary dentin (S) that in turn are surrounded by primary dentin (Pr). Both the peripheral enamel (PE) and infundibular enamel (IE) are thicker at the palatal (Pa) and buccal (B) aspects than at the interdental aspects (IA). Additionally, the enamel is thicker in ridges (↑↑) than in invaginations (↑) (x4). (Reproduced from Kilic⁷² with permission.)

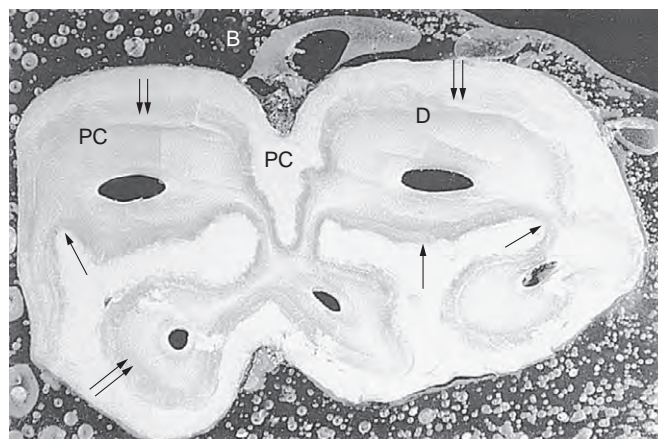


Fig. 5.9 Transverse section 2 cm beneath the occlusal surface of a methyl methacrylate embedded lower fourth cheek tooth of an 8-year-old horse. The enamel (peripheral only) is thickest (↑↑) in regions that are parallel to the long axis of the mandible and thinnest (↑) in invaginations of enamel. One peripheral infolding is apparent on the buccal (B) aspect while two deeper infoldings are present on the lingual (L) aspect. PC, peripheral cementum; D, dentin (x4). (Reproduced from Kilic⁷⁰ with permission.)

The distributions of Equine Type-1 and -2 enamels vary throughout the teeth, with Equine Type-2 enamel increasing in thickness in the peripheral enamel folds (ridges) and decreasing where these folds invaginate towards the center of the tooth (Figs 5.8 & 5.9). Almost all enamel folds contain both Type-1 and Type-2 enamel; however, increased amounts of Equine Type-1 enamel are present in the upper cheek

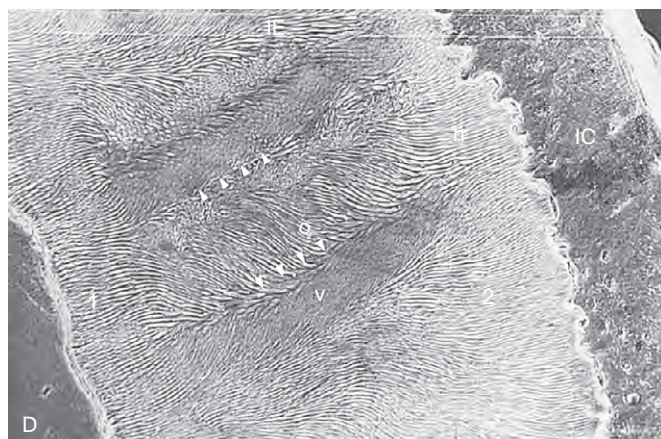


Fig. 5.10 Scanning electron micrograph of a section of an equine incisor tooth showing dentin (D) infundibular enamel (IE) and infundibular cement (IC). A thin layer of Equine Type-1 enamel is present on the left (1). The bulk of the enamel is Equine Type-2 (2) and this is oriented at a wide variety of angles including horizontal (h) obliquely (o) and vertically (v) relative to the occlusal surface. The bands of enamel oriented obliquely and vertically form alternating bands that are oriented perpendicular to the amelodentinal and amelocemental junctions with the changes in direction of the enamel bands are demarcated by grooves (VVVV) (x131). (Reproduced from Kilic et al²³ courtesy of the Editor of *Equine Veterinary Journal*.)

teeth. Similar quantities of Equine Type-1 and-2 enamel occur in the lower cheek teeth, whereas incisor enamel is composed almost solely of Equine Type-2 enamel. Equine Type-1 prisms are oriented at angles of approximately 45° to both the amelodentinal junction and the occlusal surface, but bundles of Equine Type-2 enamel prisms are oriented at a very wide variety of oblique angles.²³

Although enamel is the hardest substance in the mammalian body, it is brittle. The closely packed prisms of Equine Type-1 enamel form a composite structure including dense interprismatic plates that confer very strong wear resistance. However, these often-parallel rows of enamel prisms and interprismatic enamel are susceptible to cracking along prismatic and interprismatic lines. One adaptive process to prevent such cracks, which is particularly noticeable in Equine Type-2 enamel, is the presence of enamel decussation (which means interweaving, with changes of direction of bundles of enamel prisms that run in three-dimensions) (Fig. 5.10). In contrast, Equine Type-1 enamel has no decussation. Equine incisors are smaller and flatter than cheek teeth, have less support from adjacent teeth and yet undergo great mechanical stresses during prehension that could readily cause enamel cracks. Therefore, it is not surprising that they are largely composed of Equine Type-2 enamel prisms. Cheek teeth primarily have a grinding function, and so the presence of enamel that confers high wear resistance is more essential, and this requirement is fulfilled by the high proportion of Equine Type-1 enamel present in cheek teeth.²³ Close examination of cheek teeth enamel sometimes shows the presence of fine transverse fissures (micro fractures) through the peripheral enamel,²⁴ which does not appear to be clinically significant, as the progression of these cracks through the remaining part of the tooth often appears to be prevented by the adjacent cementum and dentin, but some fissure fractures can lead to pulpar

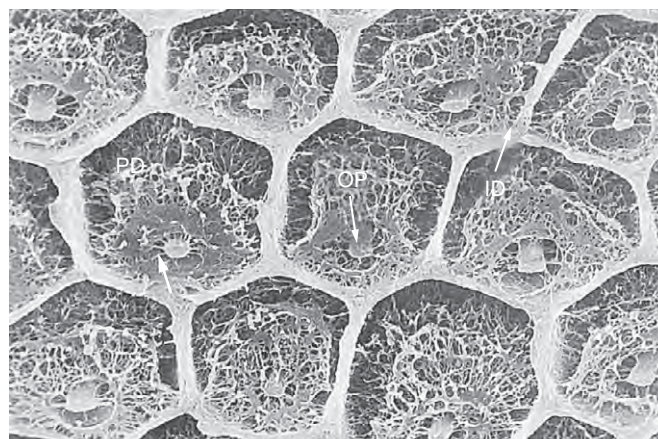


Fig. 5.11 Scanning electron micrograph of partially decalcified dentin. The hexagonal shaped intertubular dentin (ID) has a compact appearance. A network of collagenous fibers is apparent in the fully decalcified intratubular dentin (formerly termed peritubular dentin) (PD) that are attached to the odontoblast processes (OP) (x2020). (Reproduced from Kilic²² with permission.)

exposure and thus to apical infection.^{25,26} Donkeys have similar enamel types and distribution of enamel types to horses except that their maxillary cheek teeth have similar proportions of Equine Type-1 and Type-2 enamels.²⁷

In equine cheek teeth, both peripheral and infundibular enamel are about three times thicker in areas where they are parallel to the long axis of the maxillae or mandible, than where perpendicular to this axis, i.e., are invaginated into the tooth.²³ It appears that enamel may have evolved to become thinner or thicker in certain regions of the tooth in response to the level of localized masticatory forces. However, enamel thickness remains constant throughout the length of the tooth, therefore, as the animal ages the enamel thickness remains constant at the different sites in the transverse plane.

Dentin

The bulk of the tooth is composed of dentin, a cream colored, calcified tissue composed of approximately 70% minerals (mainly hydroxyapatite crystals) and 30% organic components (including collagen fibers and mucopolysaccharides) and water. The latter content is obvious in dried equine teeth specimens where the dentin (and also cement) develop artefactual cracks following loss of their water content. The mechanical properties of dentin, including its tensile strength and compressibility, are highly influenced by the arrangements and relationships of its matrix collagen fibers (Fig. 5.11), other organic components, water content and its calcified components, with the heterogeneity of its structure contributing to its overall strength.²⁸ Electron microscopic examination of equine dentin shows that it contains both calcified fibers and calcospherites. In equine teeth, the presence of dentin (and also cement) interspersed between the hard but brittle enamel layers forms an elegant laminated structure (a biological 'safety glass') allowing the two softer calcified tissues (dentin and cementum) to act as 'crack stoppers' for the enamel²⁸ as well as creating an irregular occlusal

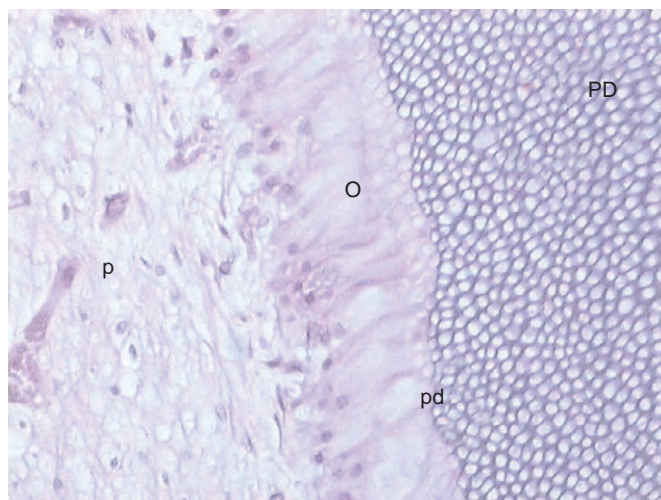


Fig. 5.12 Odontoblast cells (O) withdrawing toward the center of the pulp (p) laying down a secretory matrix i.e., a paler staining layer of predentin (pd) adjacent to the primary dentin (PD).

surface, due to the differential wear between the hard enamel and the softer cementum and dentin.

Dentin can be divided into three main types: primary dentin; secondary dentin that can be subdivided into regular and irregular secondary dentin;^{27,29,30} and tertiary dentin that forms in response to local insults that in turn can be subdivided into reactionary tertiary dentin if formed by pre-existing odontoblasts or reparative tertiary dentin if formed by previously undifferentiated mesenchymal cells.^{31,32} Even in a morphological resting phase, odontoblasts remain capable of synthesizing dentin throughout their lives if appropriately stimulated.^{13,33} Similarly undifferentiated connective tissue cells of the pulp can also be stimulated to differentiate into odontoblasts. In equine teeth, odontoblasts (Fig. 5.12) synthesize **regular secondary dentin** and also **irregular secondary dentin** on the periphery of the pulp horn throughout most of the life of the tooth, which gradually reduces the size of the pulp cavity and thus of the pulp and eventually fully occludes the pulp horn (Fig. 5.13). In equids, irregular secondary dentin is a physiological dentin that is laid down last, subocclusally in the centre of the pulp cavity and, along with regular secondary dentin, it prevents pulpal exposure with normal wear (attrition). The physiological nature of irregular secondary dentin has been shown in horse and donkey teeth, when irregular secondary dentin was present sub-occlusally in every normal cheek tooth examined histologically (Fig. 5.13).^{27,32} A recent study examining cheek teeth from 17 skulls (age range 4–30) showed the median depth of occlusal secondary dentin in mandibular and maxillary cheek teeth to be 10.8 and 9.0 mm, respectively, and does not appear to increase in thickness with age.³⁴ These values are similar to the mean occlusal secondary dentin depth determined (by CAT examinations) in donkeys of 14.6 and 13.4 mm in mandibular and maxillary cheek teeth, respectively.¹⁰ However, the donkey study showed a trend towards thicker secondary dentin in older donkeys.¹⁰

This process has great practical significance because the occlusal surface of equine teeth would otherwise develop

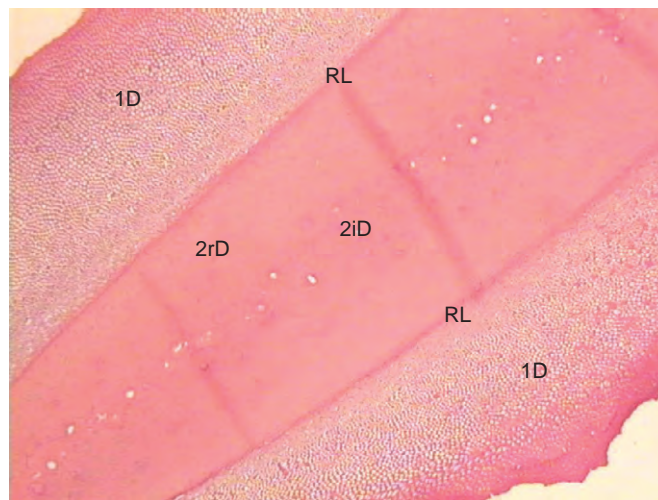


Fig. 5.13 Decalcified transverse histological section through a mandibular CT pulp horn that has become completely filled with dentin. Primary equine dentin (1D) is peripheral to regular secondary dentin (2rD) and irregular secondary dentin (2iD) with a resting line (RL) present between them (H and E).

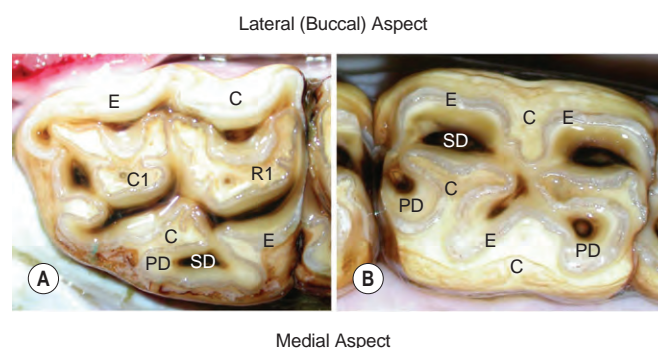


Fig. 5.14 A Triadan 11 maxillary cheek tooth (Triadan 211) showing 7 pulp horns and a Triadan 08 mandibular cheek tooth with (the standard) 5 pulp horns. The cheek tooth numbering system is presented in Fig. 5.20. C, cementum; E, enamel; PD, primary dentin; SD, secondary dentin.

exposure of the pulp horns and vital pulp, due to normal attrition on the occlusal aspect and normal eruption. Following insults to teeth, such as traumatic injury, dental caries, or excessive attrition, primary dentin can respond by developing sclerosis of the primary dentinal tubules to prevent microorganisms or their molecular products gaining access to the pulp, a defensive feature that is additional to the deposition of tertiary dentin.

As noted, the cream color of dentin largely contributes to the color of brachydont teeth. Because equine primary dentin contains very high levels of heavily mineralized intratubular dentin, it too has an almost translucent appearance, similar to enamel. In contrast, the less mineralized regular secondary dentin (produced at the site of the former pulp cavity) has a dull opaque appearance. Secondary dentin also absorbs pigments from foods such as grass (but little from grains), which give it a dark brown color that is obvious in the so-called 'dental star' of incisors³⁵ or in the brown linear areas of secondary dentin that develop on the occlusal surface of cheek teeth that are in wear (Fig. 5.14).

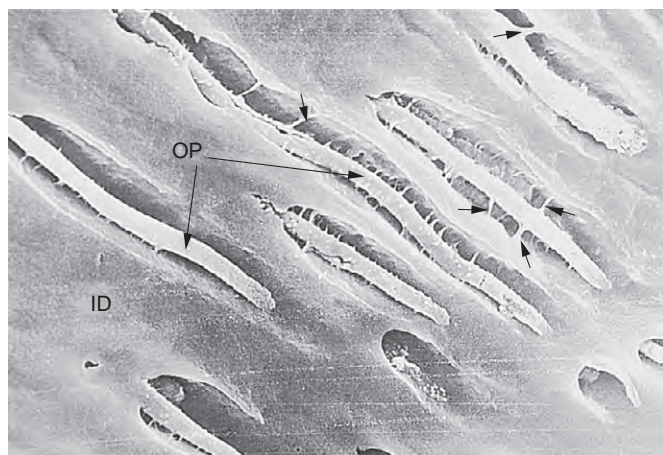


Fig. 5.15 Scanning electron micrograph of an untreated dentinal section showing a longitudinal profile of dentinal tubules containing odontoblast processes (OP) that are attached to the intertubular dentin (ID) by calcified fibrils (T) ($\times 1010$). (Reproduced from Kilic et al³⁶ courtesy of the Editor of *Equine Veterinary Journal*.)



Fig. 5.16 Scanning electron micrograph of the occlusal surface of an equine cheek tooth showing regular secondary dentin that has been etched to remove the organic pellicle. Almost all the dentinal tubules contain protruding odontoblast processes (OP) which may be calcified and many are hollow ($\times 1010$). (Reproduced from Kilic⁷² with permission.)

Dentin is composed of several distinct structures, including dentinal tubules, which are its characteristic histological feature, **intratubular dentin** (which lines the tubule walls), **intertubular dentin** (which lies between the tubules) and odontoblast processes. Dentinal tubules extend from the pulp cavity across the width of the tooth to the enamel at the amelodentinal junction. The odontoblasts reside in the predentin at the periphery of the pulp cavity, but their odontoblast processes extend through the dental tubules (Figs 5.11, 5.12 & 5.15) as far as the enamel, sometimes subdividing into two or three tubules and displaying a sharp curvature just before reaching the amelodentinal junction. There is a debate on whether the odontoblast processes reach as far as the amelodentinal junction in other species, but in the horse it appears that the odontoblast processes do reach this far.³⁶ Because there is an intimate association between the pulp and dentin that act as a single functional unit, the term **pulpodentinal complex** is appropriately used for these two tissues.³⁰ Because its tubules contain odontoblast processes, dentin is considered to be a sensitive living tissue and thus mechanical interference with dentin, e.g., reducing larger overgrowths that contain dentin, can damage sensitive odontoblast processes and can thus potentially cause pain.³⁷

In brachydont species, odontoblast processes or their surrounding fluid can convey pain signals from insulted (e.g., by excessive heat or cold, trauma, infection) dentin to the pulp, by incompletely understood mechanisms. In horses, where exposed dentin constitutes a major part of the occlusal surface, it is most unlikely that such a pain-producing mechanism exist on the normal occlusal surface. It is interesting that on the occlusal surface of normal equine teeth, apparently intact, odontoblast-like processes are visible protruding from the dentinal tubules of primary and regular secondary dentin (Fig. 5.16), even though this area is constantly exposed to oral microbial and biochemical insults³⁸ and pulpar infection is rare. A possible explanation for their apparently undamaged morphology is that they have become calcified. Some studies have suggested that these structures are not odontoblast processes, but are in fact collagen fibrils,

termed laminae limitantes, that are the un-mineralized inner layer of intratubular dentin.³⁹ However, even if microorganisms could enter patent dentinal tubules on the occlusal surface, they may not reach the pulp cavity because the dentinal tubules are sealed by a smear layer of ground dental tissue and additionally, retrograde flow of fluid from the pulp through the dentinal tubules to the occlusal surface⁴⁰ may also prevent descent of microorganisms down these tubules. Irregular (reparative) secondary dentin is less organized than primary dentin and contains no odontoblast processes as its dentinal tubules are fully obliterated. This type of dentin can fully seal off the pulp from the oral environment.

Intratubular dentin (Fig. 5.11) has a higher mineral content than intertubular dentin and therefore has a higher resistance to wear. A transitional region exists between equine primary and secondary dentin where intratubular dentin is absent, and is sometimes very distinct histologically.³² Because regular secondary dentin contains no (dense) intratubular dentin, it is more susceptible to attrition than primary dentin. Likewise, the dentin near the amelodentinal junction contains the lowest amounts of intratubular dentin and would theoretically be expected to wear faster; however, it is protected from excessive wear by the adjacent enamel.

Pulp

The histology of equine teeth pulp has been poorly evaluated to date, with most information derived from studies on brachydont teeth pulp. Pulp is a soft tissue within the dental pulp cavities that contains a connective tissue skeleton, including fibroblasts, thick collagen fibers and a network of fine reticulin fibers, connective tissue cells (that, as previously noted, can differentiate into odontoblasts if appropriately stimulated), extensive vasculature (to allow active continuous secondary dentin deposition), lymphatics, and nerves (sensory and vasoregulatory). In mature teeth, pulp is contiguous with the periodontal connective tissue at the

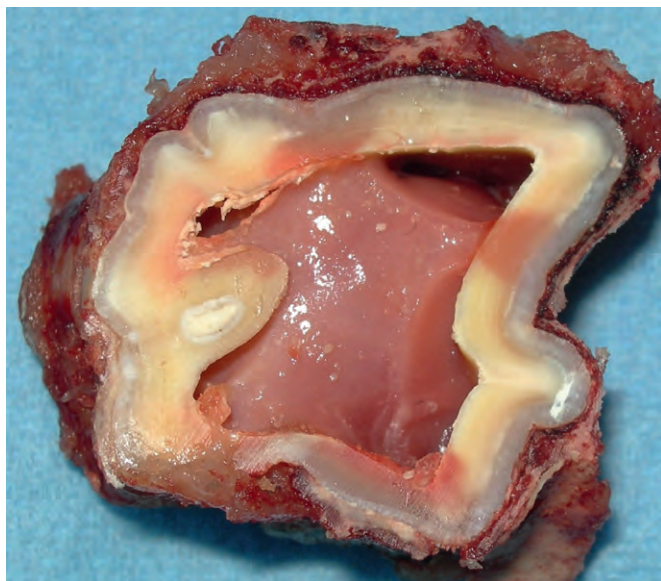


Fig. 5.17 Transverse section of a young equine maxillary cheek tooth sectioned just above the apex showing the common pulp chamber that later will become divided into separate pulp horns. A thick vascular periodontal membrane surrounds a thin layer (not apparent in some areas) of cementum that overlies the almost translucent layer of enamel that, in turn, overlies a layer of thicker cream-colored dentin.

apical foramen. A thin layer of predentin (that becomes thinner in older brachydont teeth) lies between the formed dentin and pulp periphery that contains the odontoblasts (Fig. 5.12) whose cytoplasmic processes extend into the dentinal tubules.

At eruption, equine permanent teeth possess a large common pulp (Fig. 5.17) that is contiguous with the primordial pulp that surrounds the developing apices (Figs. 5.18 & 5.19). At the apex of these young teeth, a thin layer of enamel surrounds this pulp. Later, following deposition of apical dentin and cement, roots are developing well in all equine cheek teeth by *circa* 2 years after eruption. One study suggested that separate pulp canals may not develop in mandibular cheek tooth until 5–6 years following eruption,⁹ but more extensive studies of both mandibular and maxillary CT have shown separate pulp horn development 1 year following cheek teeth eruption.³² The distinct anatomical features of equine cheek teeth pulps have significant implications for endodontic therapy. The 07s to the 10s all contain 5 pulp horns but the fully-developed 06s and mandibular 11s usually contain 6 and the maxillary 11s have 7 pulp horns.^{32,41} Whilst the original pulp horn classification of Dacre^{32,41,42} was a major step forward, its use of differing pulp numberings for upper and lower CT has caused some confusion. Consequently, a modified pulp classification¹⁰ is used in this text (Fig. 5.20). Equine incisors are similar to brachydont incisors in having just a single pulp.

Unlike brachydont teeth, hypsodont teeth need to continue to lay down secondary dentin over a prolonged period (most of their life) in order to prevent occlusal pulp exposure. Consequently, in order to supply the metabolically active odontoblasts, the apical foramina through which the tooth vasculature passes into the pulp must remain relatively dilated ('open') for a prolonged period, although progressive

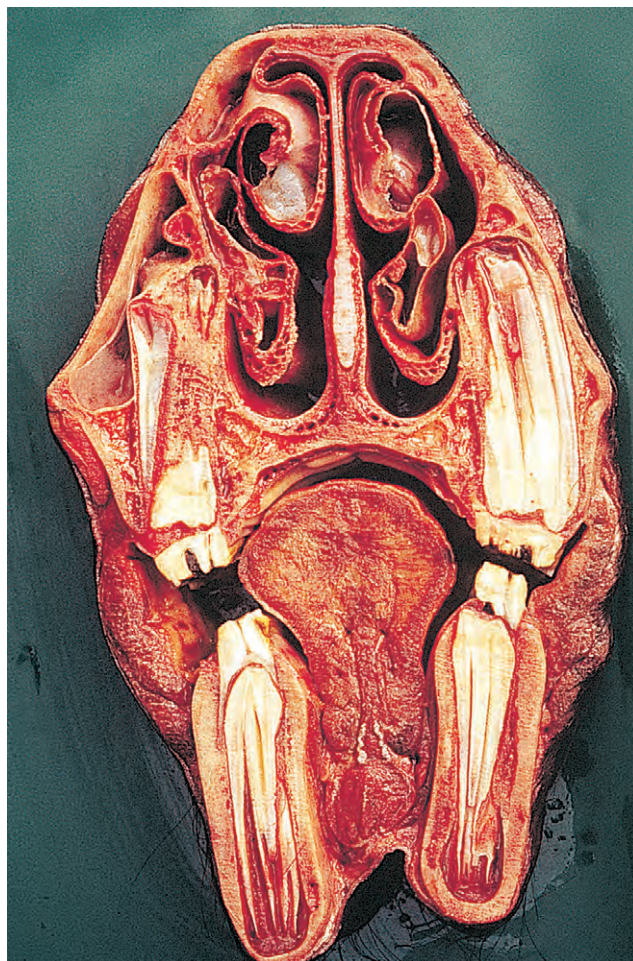


Fig. 5.18 Transverse section of the skull of a 3.5-year-old horse at the level of the 207 (second right maxillary cheek tooth) and between 107 and 108 on the left with part of 108 lying within the rostral maxillary sinus. Note the remnants of the deciduous teeth ('caps'), the angulation of the occlusal surfaces, and the anisognathia. There are wide common pulp chambers of the apices of the permanent teeth and absence of roots. The infundibula of the temporary maxillary teeth have cemental hypoplasia.

reduction in foramen size does occur with age.⁴³ The apical foramina also become displaced more occlusally by continued cement deposition at the apical aspect of the teeth with age. Kirkland et al found constricted ('closed') apical foramina in equine mandibular cheek by 5–8 years after their eruption, with development of two apical foramina in the rostral root.⁹ This is in contrast to the apical foramina of brachydont teeth which become more rapidly and extensively constricted ('closed') by deposition of secondary dentin within the pulp canal¹ and also by cement deposition externally.

A practical result of these features is that pulp exposure in mature brachydont teeth causes pulpitis due to pH changes, irritation from molecules in saliva and foodstuffs, and an inevitable bacterial infection. The resultant pulpar inflammation within the totally rigid confines of the pulp chamber compresses the limited pulpar vasculature, usually leading to pulpar ischemia and necrosis, resulting in the death of the tooth. However, in hypsodont teeth, especially when young,

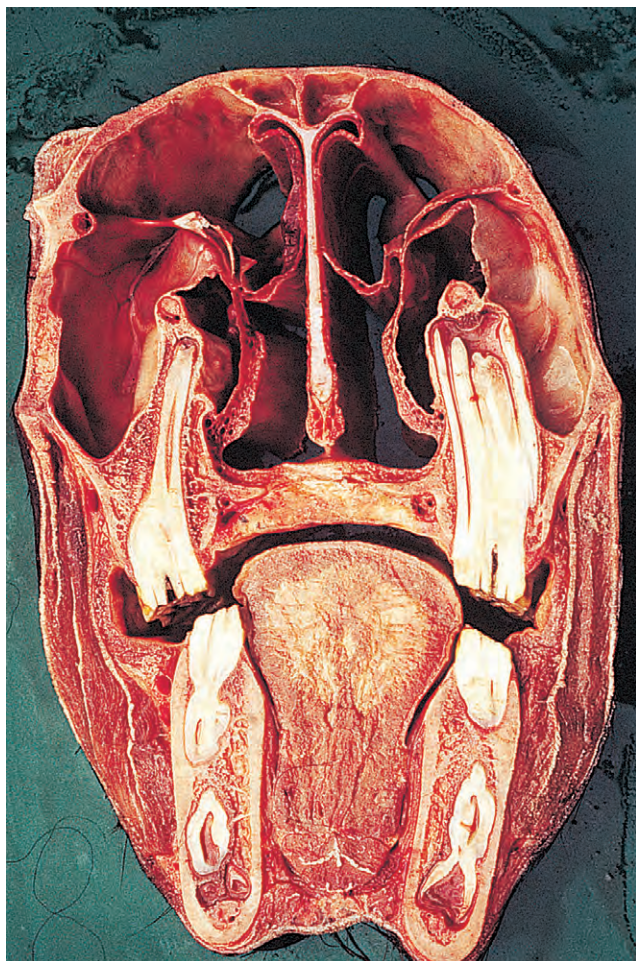


Fig. 5.19 Transverse section of the skull of a 3.5-year-old horse at the level of the 110 and 210 (with overlying infra-orbital canals) that lie at the junction of the rostral and caudal maxillary sinuses. Due to their curvature, parts of the mandibular 10s and 11s are shown. The mandibular canal lies on the ventromedial aspect of the mandible. The wide common pulp cavity of 210 has pulp horns that extend to within 1 cm of the occlusal surface.

the dilated apices and good blood supply often allows the pulp to withstand such inflammation by maintaining its blood supply. Local macrophages within the pulp, along with extravasated white blood cells and their molecules can then control pulpar infection. Additionally, the odontoblasts laying down secondary dentin can also lay down reactionary tertiary dentin in response to infection of the overlying dentin or following traumatic pulp exposure. In the absence of sufficient local odontoblasts as noted, adjacent undifferentiated connective tissue cells or fibroblasts in the pulp can transform into odontoblasts and lay down tertiary reparative dentin to seal off the exposed pulp from the healthy more apically situated pulp.

In addition to progressive, complete occlusion of the pulp horn beneath their occlusal aspect with secondary dentin, a continuous, but slower deposition of secondary dentin over all of the pulp horn walls causes the overall pulp size to reduce with age, as the surrounding dentin becomes thicker. A practical consequence of this is that the cheek teeth in younger (e.g. <7–8 year old) horses contain a high proportion of hard but brittle enamel with minimal secondary

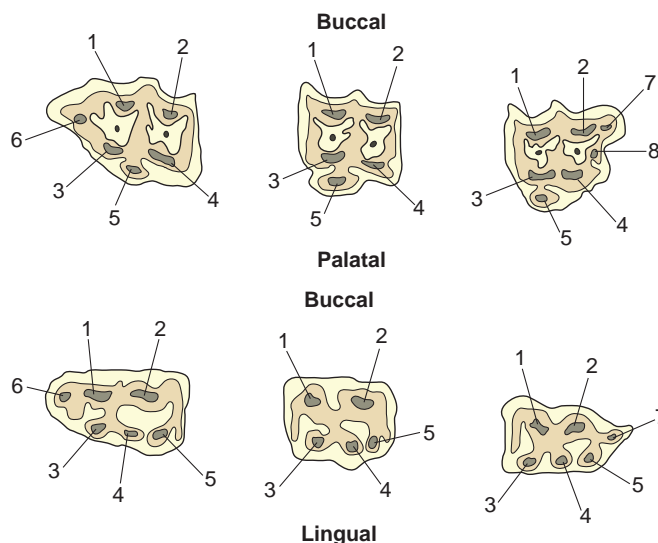


Fig. 5.20 A revised cheek teeth pulp numbering system (maxillary cheek teeth on top row and mandibular cheek teeth on bottom row) as described by du Toit et al.¹⁰

dentin, and thus are somewhat shell-like. These teeth are readily rasped but may fracture if cut with shears (whose use is no longer advocated – as mechanical burrs are much safer). In contrast, the teeth of older horses contain large amounts of secondary dentin, which makes them more solid and less likely to shatter when cut, but more difficult to rasp (float) than young teeth. With age, the pulp of brachydont teeth loses much of its vasculature, fibroblasts, and odontoblasts, while its collagen content increases. This process should be delayed in equine teeth due to the prolonged, higher metabolic requirements of their pulp to allow prolonged secondary dentin deposition (Fig. 5.12).

Cement

Cement (cementum) is a white or cream-colored, calcified dental tissue with mechanical characteristics and a histological appearance similar to bone. It contains circa 65% inorganic (again mainly impure hydroxyapatite crystals) and 35% organic and water components. Similar to dentin, its high organic and water content give it flexibility. The organic component of cement is comprised mainly of extensive collagen fibers, which include small intrinsic fibrils (produced by cementoblasts) and larger extrinsic fibers (produced by fibroblasts of the periodontal membrane), some of which form tight bundles termed **Sharpey's fibers** (median 2.5 microns in diameter in horses) that cross the periodontal space to become anchored in the alveolar bone³ (Fig. 5.21), thus indirectly attaching the cement and alveolar bone. Cementum may be variously classified by its cellular content, i.e., cellular or acellular; its anatomical location, i.e., peripheral or infundibular; or coronal or root. A recent study examining cell proliferation within the equine periodontium demonstrated that a dynamic process of cell proliferation and migration is involved in the periodontal ligament remodeling associated with continued eruption.⁴⁴ The recent successful culture of equine periodontal

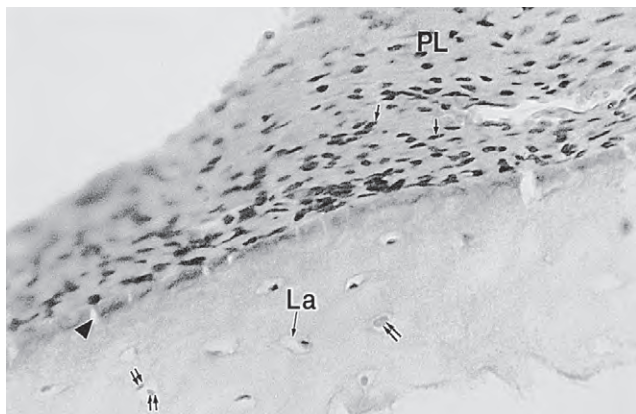


Fig. 5.21 Light microscopy of the periphery of an upper cheek tooth showing the periodontal ligament (PL) containing fibroblast-like cells (↑). The adjacent peripheral cement contains lacunae (La) of the cementoblasts (↑↑). Projections of the periodontal ligament into the cementum (arrowhead) probably represent Sharpey's fibers (x1000). (Reproduced from Kilic et al²² courtesy of the Editor of *Equine Veterinary Journal*.)

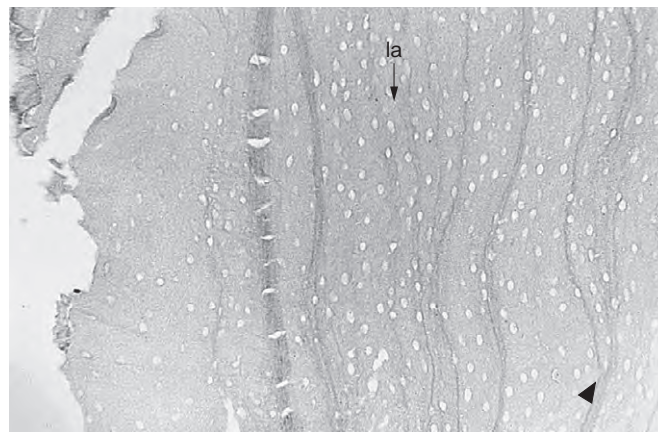


Fig. 5.22 Light micrograph of the peripheral cement of the deep reserve crown (adjacent to the apex) of a recently erupted cheek tooth. This contains wavy incremental lines (arrowhead) between successive depositions of cement that have occurred even at this early stage of tooth growth. Cementoblast lacunae (la) are present at all levels of the cement (x44). (Reproduced from Kilic⁷² with permission.)

fibroblasts and equine dental cementoblasts will result in better elucidation of the process of continued eruption.⁴⁵

Under polarized light, undecalcified (ground) transverse sections of equine CT show two distinct regions. Adjacent to the peripheral amelocemental junction, the crystalloid nature of the cementum has irregular orientation of its hydroxyapatite crystal similar to those of maxillary CT infundibular cement. More peripherally, the crystal orientation changes to a more regular pattern, with the crystals having a similar concentric orientation. 'Peripheral lines' may be observed in decalcified transverse sections in this more peripheral zone. These two zones of regular and irregular peripheral cementum are most obvious in sections of older teeth near the occlusal surface.

Like dentin, cement (of the subgingival area and a few millimeters more occlusally, i.e., of reserve crown and roots) is a living tissue with its cells (cementoblasts) nourished by the vasculature of the periodontal ligament.² Peripheral cement and the adjacent periodontal membrane can be considered as a single functional unit²⁹ (as are dentin and pulp). After eruption onto the clinical crown, cementoblasts lose their blood supply from the periodontium and, in general, cement on the clinical (erupted) crown can be regarded as an inert tissue. However, recent work has shown active vasculature extending from the gingival margin beneath the surface of cementum on the clinical crown.^{2,27} Cement is the most adaptable of the calcified dental tissues and can be quickly deposited (within the alveolus or subgingivally) in response to insults such as infection or trauma,⁴⁶ as commonly observed in some teeth with chronic apical infections.^{25,26} As noted earlier, hypsodont teeth have cementum covering all of the crown at eruption (including the occlusal surface) but the latter is soon worn away after eruption. Cement also fills the infundibula, usually incompletely at eruption.²¹

In hypsodont teeth, cement deposition continues throughout the life of the tooth, both around the roots (root cement) and also on the reserve crown (coronal cement) (Fig. 5.22). The latter allows new Sharpey's fibers (Fig. 5.23) to be laid

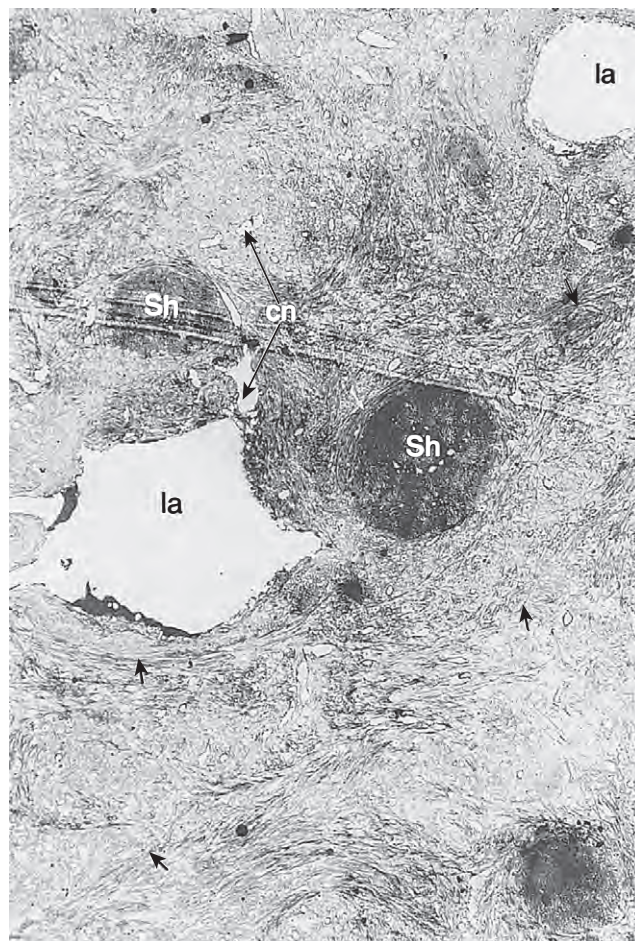


Fig. 5.23 Transmission electron micrograph of peripheral cement of a cheek tooth. This shows irregularly shaped lacunae (la) and their canaliculae (cn) but the cementoblasts have been lost during sample preparation. The dense Sharpey's fibers (Sh) have been transversely sectioned. The intrinsic fibrils of the cement (↑) are also apparent (x2150). (Reproduced from Kilic et al,²² courtesy of the Editor of *Equine Veterinary Journal*.)

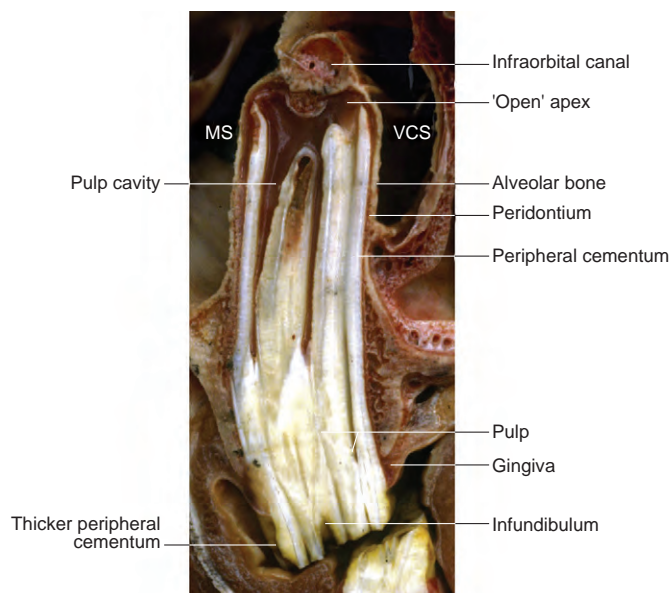


Fig. 5.24 Longitudinal section of a young maxillary cheek tooth lying in the maxillary sinus (MS) and ventral conchal sinus (VCS). Note the very extensive common pulp chamber and large pulp horns and thus a limited amount of (secondary) dentin present, which is characteristic of young equine teeth. Localized (clinically insignificant) central cemental caries is present in the transected infundibulum. The alveolar bone and periodontal membrane can be identified adjacent to the cement at the periphery of the tooth. Note the increase in thickness of the peripheral cement (of the 'gingival reserve crown') immediately following eruption of the tooth from the alveolus.

down, a process required to allow the necessary prolonged eruption of hypsodont teeth and also to allow additional cement deposition to mechanically contribute to the clinical crown. However, further cement cannot be deposited in the more occlusal aspect of the infundibulum that has lost its blood supply following tooth eruption, or more apically in the infundibulum unless some apical vasculature remains;²¹ likewise on the cement of the clinical crown once it moves a few millimetres away from the gingiva.¹⁰ The main functions of cement are to provide anchorage for fibers of the periodontal ligament that support (with some flexibility) the tooth in the alveolus, and to protect the underlying dentin at the dental apex, and these two features of cement are present in both brachydont and hypsodont teeth. However, in hypsodont teeth, cement has major additional roles by contributing significantly to the bulk and thus mechanical strength of the clinical crown (especially in the lower cheek teeth), protecting the coronal enamel from cracking and helping form the protruding enamel ridges on the occlusal surface.^{2,43} The mandibular cheek teeth have a greater amount of peripheral cementum than maxillary cheek teeth.¹⁰

To provide additional cement on the clinical crown, there is a large increase in cement deposition, once the tooth exits from the rigid spatial restrictions of the alveolus² (Fig. 5.24). In some aged horses, the dental remnants exposed at the occlusal surface may eventually be composed only of roots (dentin and cement) with surrounding heavy cemental deposits. As this dental remnant contains no enamel, it becomes smooth on its occlusal surface (**smooth mouth**) and wears away quickly (Fig. 5.25).



Fig. 5.25 Occlusal view of a maxillary cheek teeth row of an aged horse. Just the roots (with the rostral roots separated) remain of the 109 and 111 that have heavy peripheral cement deposits. These remnants contain little enamel ('smooth mouth') and consequently are ineffective at grinding forage and will soon fully wear out. The infundibula of some of the remaining teeth have fully worn out, and diastemata are present between some teeth.



Fig. 5.26 Scanning electron micrograph of a mid tooth transverse section of the infundibular area of a maxillary cheek tooth of a 14-year-old horse. This contains dentin (D), an amelodentinal junction (ADJ), infundibular enamel (IE), and infundibular cement (IC). The infundibular cement shows extensive hypoplasia and areas of porous cementum with the large central defect partially lined by shrunken organic tissue (arrowheads). The infundibular enamel is exposed in several areas (x10.6). (Reproduced from Kilic et al,³¹ courtesy of the Editor of *Equine Veterinary Journal*.)

A thin layer of peripheral cement covers the incisors and canine teeth, but much greater amounts overlie the cheek teeth, where its thickness varies greatly, largely depending on the degree of infolding of peripheral enamel. Peripheral cement is thickest in deeply infolded areas, especially in the two deep infoldings on the medial aspect of the lower cheek teeth (Fig. 5.9). At these sites, especially towards the tooth apex, this thick peripheral cement can be fully enclosed by these deep enamel folds, and these areas of cement can resemble infundibula.

As noted, the infundibula (in all incisors and the upper cheek teeth) are usually incompletely filled by (infundibular) cement. Kilic et al²² found that in addition to the 24% of (upper) cheek teeth that had gross caries (mineralized dental tissue dissolution) of their infundibular cement (Fig. 5.26), a further 65% of horses had one or more small

central vascular channels in this cement.^{22,38} These channels extended from the occlusal surface to a variable depth and contained smaller lateral channels extending as far as the infundibular enamel. This type of cement hypoplasia was termed *central infundibular cemental hypoplasia*. In addition, some infundibula had linear areas of cement hypoplasia at the enamel junction termed *junctional cemental hypoplasia*.²² As this latter cemental hypoplasia was commonly found in incisor infundibula, that show little evidence of caries (albeit they are much shallower infundibula than those of cheek teeth), consequently junctional cemental hypoplasia is not believed to be clinically significant.²² A more recent study showed infundibular cemental hypoplasia present in 22% of 786 maxillary cheek teeth infundibula, with discoloration of an often porous-appearing infundibular cement present in 72% of infundibula and true cemental caries present in 8% of infundibula (Figs 5.27 & 5.28). The most marked cemental hypoplasia was present in the apical third of the infundibula.²¹ As only 15% of the infundibula were completely filled with normal cementum, the hypoplasia (Figs 5.27–5.29) and discoloration so commonly observed in this study further supports the theory that cemental hypoplasia and discoloration could almost be considered as normal anatomical variations. Viable cementocytes and an active local blood supply were found in the more apical aspects of infundibula in one study (Figs 5.28 & 5.29).²¹

The occlusal surface

At eruption, the crown, including the occlusal surface of equine teeth, is fully covered by coronal cement, which in turn covers a thin layer of coronal enamel. With normal occlusal wear, the coronal cement and coronal enamel are very soon worn away thus exposing the **secondary occlusal surface** of these teeth, which is the permanent occlusal surface of hypsodont teeth (Fig. 5.3). The normal wear process, i.e., **attrition** on the occlusal surface of hypsodont teeth is a complex phenomenon depending on many factors,



Fig. 5.27 Longitudinal section of a young maxillary cheek tooth circa 10 cm long with an infundibulum of 90% of that length. Note the central area of discolored darker staining infundibular cementum that represents the site of the central vascular channel. Two pulp horns derived from the common pulp chamber are partially visible except at their occlusal aspects. Enamel extends to the full extent of the immature apex indicating absence of root development. Note the extensive peridontal attachments peripherally.



Fig. 5.28 Longitudinal section of a recently erupted maxillary cheek tooth with both infundibula partly exposed. The outlines of both infundibula are curved and irregular with a dilation of one infundibulum near its apex that additionally contains some vascular cementum with a blood supply from the apical area. This infundibulum also has a central cemental defect running through almost all of the infundibulum with more marked dark food-staining present 2–3 cm subocclusally. Note that one pulp horn contains viable pulp circa 5 mm sub-occlusally.

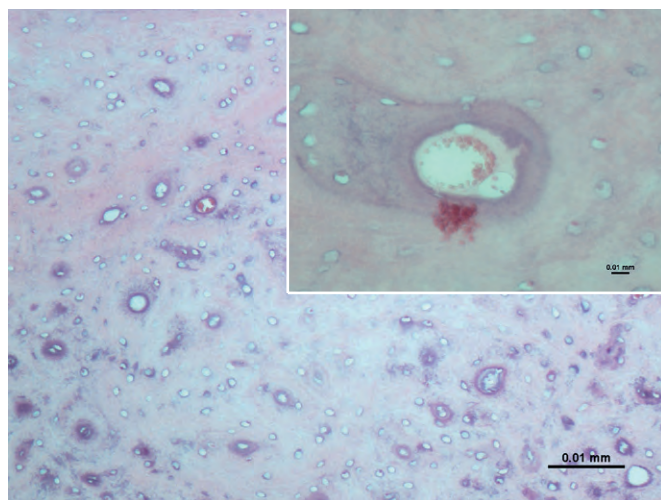


Fig. 5.29 Decalcified histological section of infundibular cementum from a 109 in a 3-year-old horse showing viable cementocytes within the lacunae ($\times 100$). Inset picture shows a viable infundibular cemental blood vessel with red blood cells ($\times 400$).

including the type of diet, e.g., in the winter outdoor horses may be forced to graze lower and thus ingest more soil-covered roots and leaves, or even eat the roots of plants such as nettles (M. Booth 1996, personal communications), thus greatly increasing the amount of silicates that are ingested. When grazing is scarce, they may also eat coarser food, including bushes, such as gorse. The duration of eating also varies according to the season from up to 13 hours/day in summer to 16.5 hours/day in winter in outdoor horses, in some environments (M Booth 1996, personal communications). While eating hay, horses and ponies have 58–66 chews a minute, with 4200 chews/Kg of dry matter,⁴⁷ whilst at grass they have 100–105 chewing movements per minute.⁴⁸ Dental attrition also depends on the force and the direction of the chewing action, the sizes, shapes, and angles of the opposing occlusal surfaces, and the relationship of opposing cusps and crest patterns to the occlusal motion. Horses eating roughage exhibit a more lateral masticatory action compared with horses eating a concentrate/pelleted diet, which have a more vertical crushing stroke.^{49,50} Consequently, painful oral disorders can cause changes in the direction and forces of mastication and thus affect the wear patterns of cheek teeth, as further discussed in Chapters 6 and 9.

The occlusal surfaces of equine teeth are covered by an organic pellicle³⁸ containing microorganisms, small food particles, and a smear layer of finely ground dental particles formed by masticatory actions. The underlying enamel contains differing wear patterns, including polished areas, small local fractures, pit striations, and depressions. Most large striations are at right angles to the long axis of the cheek teeth rows (i.e., in the buccolingual/palatal plane) and appear to be caused by the normal side-to-side chewing motion of the cheek teeth when grinding down small ingested phytoliths (calcified plant particles). Scanning electron microscopy of such deep grooves shows that prismatic enamel is more deeply worn than interprismatic enamel, confirming that the former structures are softer.

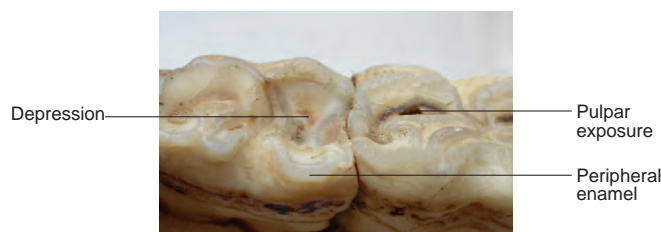


Fig. 5.30 Occlusal aspect of two aged mandibular cheek teeth with the tooth on the left showing limited peripheral cement infolding of its caudal aspect – with consequent excessive wear of the adjacent dentin causing a depression in this area of the occlusal surface ('cupping' 'senile excavation'). The adjacent cheek tooth has normal enamel infolding but has occlusal exposure of one of its pulps.

Additionally, some shorter striations are present on the occlusal surface of equine teeth perpendicular to the buccolingual/palatal plane (at right angles to the normal chewing direction), and it is suggested that these striations are caused by ingested phytoliths during the crushing phase of chewing.³⁸

The softer dentin on the occlusal surface wears faster than the surrounding enamel, and therefore the dentinal surface becomes depressed, relative to the adjacent enamel. The depth of these depressions is directly related to the area of occlusal dentin, with larger exposed areas more deeply recessed.³⁸ In contrast, smaller areas of occlusal dentin are better protected from wear by the adjacent enamel folds and so undergo less wear and have shallower depressions on their surface. Therefore, the orientation and invaginations of the enamel folds (peripheral and infundibular) play an important role in dividing the occlusal surface of dentin into smaller areas and thus protecting it from excessive attrition. The lower cheek teeth have three very deep infoldings of enamel, two on the medial (lingual) aspect and one on the buccal aspect. The upper cheek teeth have less marked peripheral enamel infoldings; however, they contain two enamel-containing infundibula, which further subdivides and compartmentalize their occlusal dentin, thus protecting it from excessive wear centrally in the teeth.³⁸ The ratio of peripheral enamel length to tooth perimeter on sub-occlusal transverse sections is greater in maxillary cheek teeth with infundibular enamel (1.87) compared to mandibular cheek teeth (1.48) despite the greater peripheral enamel infolding present in mandibular cheek teeth.¹⁰ There is usually less infolding of peripheral enamel folds more apically in teeth, and therefore some older teeth may show excessive dentinal wear at such unprotected areas (Fig. 5.30). Similarly, if infundibula (in upper cheek teeth) are absent or are short and wear away prematurely, excessive local dentinal wear also occurs centrally in such teeth (Fig. 5.31). A study of normal infundibula has shown lengths (depths) from 89 mm (in a 4-year-old horse) to 2 mm (in a 30-year-old horse), with infundibular length being a mean of 82 % of the total dental crown length.²¹

Gross Anatomy of Equine Teeth

Incisors

The deciduous 01s (central incisors), 02s (middle-intermediate) and 03s (corner) incisors erupt within a few

days of birth, 4–6 weeks, and 6–9 months of age, respectively.⁵¹ Deciduous incisors are whiter and contain wider and shallower infundibula than their permanent successors, which erupt on their lingual aspect. As noted, the eruption of both deciduous and permanent teeth can be used to estimate the age of horses up to 5 years old with a reasonable degree of accuracy^{52,53} (see Ch. 7).

The dental formula of deciduous and permanent teeth in horses

Deciduous teeth: $2(Di\ 3/3, Dc\ 0/0, Dm\ 3/3) = 24$ teeth

Permanent teeth:

$2(I\ 3/3, C\ 1/1\ \text{or}\ 0/0, PM\ 3/3\ \text{or}\ 4/4, M\ 3/3)$
= 36 to 44 teeth

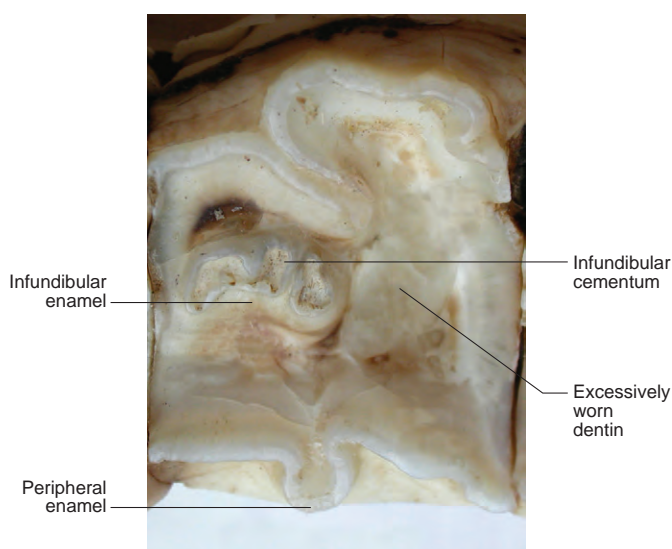


Fig. 5.31 Occlusal surface of a maxillary cheek tooth that is missing one of its infundibula with resultant excessive wear causing a deep depression ('cupping' 'senile excavation') in the occlusal surface at this site. Such 'cupping' may predispose to sharp overgrowths on the lateral and medial aspects of upper and lower cheek teeth in older horses. Unusually the remaining infundibulum appears to consist of two separate smaller infundibula.

depending on the presence and number of canine teeth or 1st premolar (wolf teeth).⁵⁴

The Triadan System of dental nomenclature utilizes three digits to identify each tooth. The first digit refers to the quadrant, with 1 for upper right, 2 for upper left, 3 for lower left, and 4 for lower right (Fig. 5.32).⁵⁵ The deciduous teeth are similarly identified using the prefix 5–8 for the four quadrants.

Adult horses also have 12 incisors in total, six in each arcade. The upper incisor teeth are embedded in the premaxillary (incisive) bone, and the lower incisors in the rostral mandible, with the reserve crowns and apices of incisors converging towards each other. Incisor teeth are curved convexly on their labial aspect (concavely on their lingual aspect) and taper in uniformly from the occlusal surface toward the apex (unlike equine deciduous incisors, and all brachydont incisors that have a distinct neck). Therefore with age, spaces eventually develop between equine permanent incisors, but the development of these spaces is delayed by the medial (mesial) pressure of the 03s on the remaining incisors. The fully developed incisor arcade in a young adult horse has an almost semicircular appearance, which gradually becomes shallower with age, due to alteration of teeth shape caused by progressive wear.⁵⁶ The occlusal angle of incisors also changes from almost vertical apposition in the young horse (Fig. 5.33) to an increasing angle of incidence with age.

Equine incisors also develop certain wear-related macroscopic features that have been traditionally (if not very accurately) utilized for estimating age^{52–54} as discussed in detail in Chapter 7. The infundibulum present in all incisors is termed the incisal cup ('cup'). This funnel-like enamel structure is oval in shape and circa 10 mm deep when the tooth first erupts. However, variations in its depth may cause the infundibulum to wear away more rapidly or slower than 'normal' and thus make aging difficult. The incisor infundibulum is usually incompletely filled with cement and consequently later becomes filled with food material and appears dark.⁵² When the infundibular cavity is worn away, it leaves behind a small ring of the remaining apical aspect of the infundibular enamel, located on the lingual aspect of the tooth, which is called the **enamel spot (enamel ring or mark)**.⁵² Due to the slower wear of enamel as

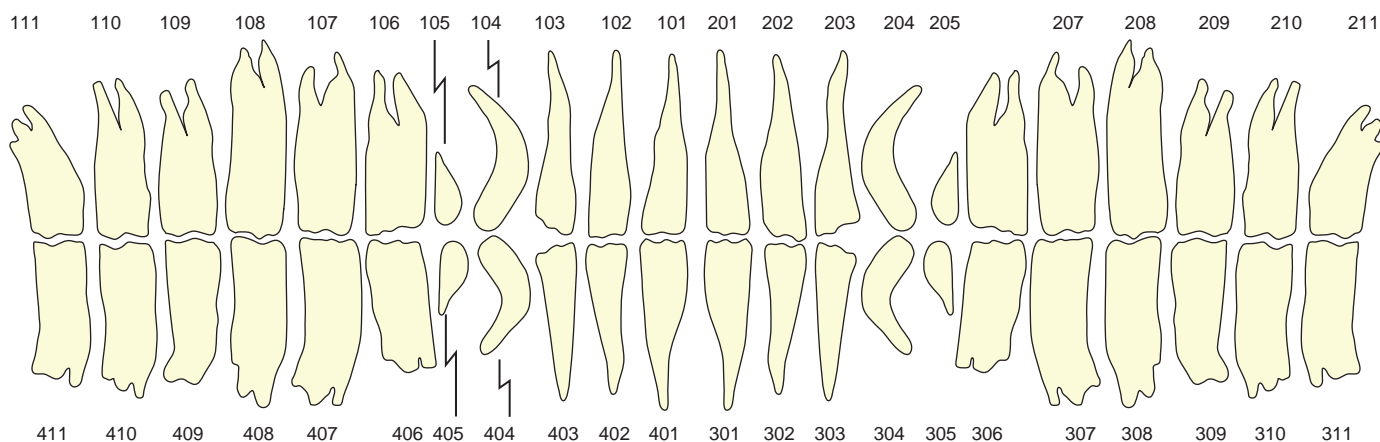


Fig. 5.32 The Triadan classification of equine teeth.

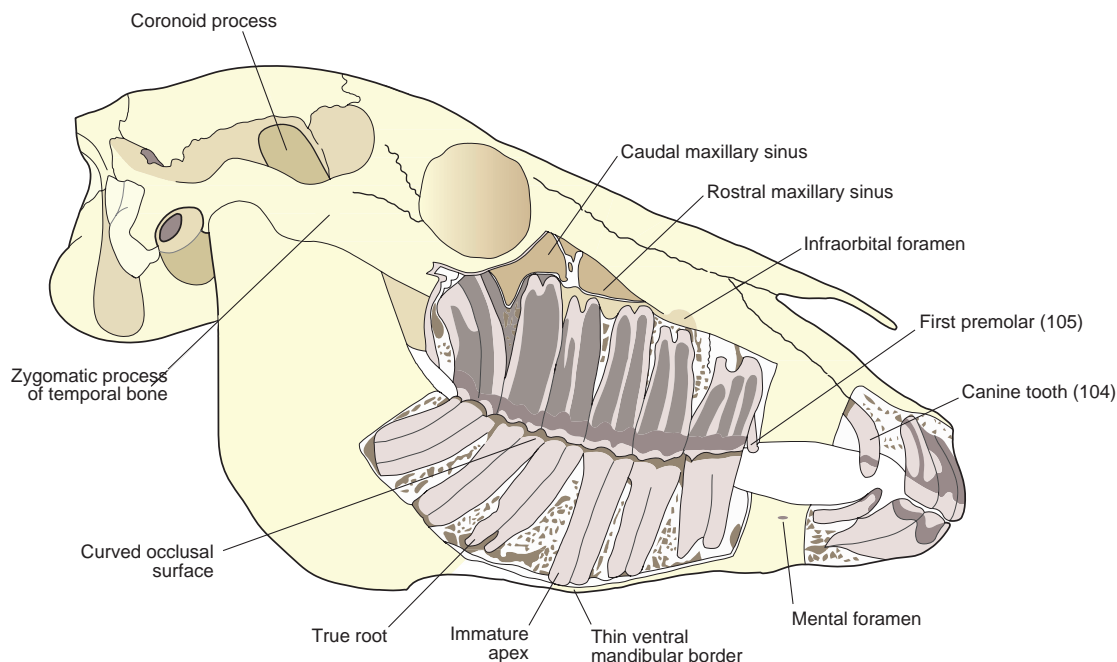


Fig. 5.33 Diagram of a skull of a 5-year-old horse demonstrating ventral deviation of the mandible associated with eruption of 408. Note the shape and apposition of the incisors of this young horse. The angulation of the rostral and caudal cheek teeth and the curvature of the sixth teeth maintain tight apposition of all six cheek teeth at the occlusal surface. The TMJ is high (approximately 15 cm higher in an adult Thoroughbred) above the level of the cheek teeth occlusal surface. Note the small coronoid process and the large area of muscle attachment of the mandible.

compared to dentin, the enamel spot becomes elevated above the occlusal surface. The **dental star** represents exposure of secondary (regular and irregular) dentin on the occlusal surface of incisor teeth that was deposited in the former pulp cavity. It appears sequentially in the 01s, 02s and 03s (see Ch. 7). This secondary dentin initially appears as a dark yellow (due to food staining), transverse line on the labial aspect of the infundibulum. With further tooth wear, it gradually becomes oval in shape and moves toward the centre of the occlusal surface.

Galvayne's groove is a longitudinal groove that appears on the labial aspect of the permanent upper 03s (corner incisors), and is traditionally stated to first appear at about 10 years of age, reaching halfway down the tooth by 15 years of age and extending to the occlusal surface by 20 years of age. However, recent critical studies, as reviewed in Chapter 7, have shown much variation in the time that these features develop. Another, variable anatomical feature is the development of a 'hook' (a colloquial term for a localized dental overgrowth) on the caudolabial aspect of the occlusal surface of 103 and 203 after circa 6 years of age, due to incomplete occlusal contact between the upper and lower 03s. It is often termed a '7 year notch or hook' because it was traditionally (but erroneously) believed to always appear at 7 years of age.^{7,56} Variations in incisor teeth appearance can also be due to individual and breed variation, differences in diets, environmental conditions, eruption times, mineralization rates, depth of enamel infundibulum, amount of infundibular cement and the presence of certain stereotypic behaviors, such as crib-biting and wind sucking.^{57,58} The occlusal surface of individual incisors is elliptical in recently erupted incisors, but, with wear, they successively become round, triangular,

and then oval in shape. These changes are more apparent in the lower 01s and 02s than in the lower 03s.^{53,54}

Canine teeth

The deciduous canine teeth (Triadan 504, 604, 704 and 804) are vestigial spicule-like structures, 0.5–1.0 cm long, that do not erupt above gum level. The lower deciduous canine is situated caudal to the 03s (corner incisor).⁵¹ Male horses normally have four permanent canine teeth, two maxillary (104, 204) and two mandibular (304, 404), that erupt between 4 and 6 years of age in the interdental space (physiological diastema).⁵⁴ They are often stated to be simple teeth, but while they have no enamel infolding, their clinical crown is covered in peripheral cementum, and some degree of prolonged eruption can occur. Canine teeth have a pointed occlusal surface, are convex on their buccal border, and slightly concave on their medial (lingual and buccal) aspect, with a slight caudal facing curvature. The lower canines are more rostrally positioned than the upper, and thus there is no occlusal contact between them. This is alleged to be a reason why canine teeth (especially the lowers) are prone to develop calculus. Canine teeth are usually absent or rudimentary in female horses, with a reported prevalence of 7.8–28% in horses⁵⁷ and 17.3–30% in donkeys.⁵⁹ Canines do not continually erupt like cheek teeth, and thus long reserve crowns can be present in older horses. In the young adult Thoroughbred, canine teeth are 5–7 cm long with most present as unerupted crown. In some horses, just 10–20% of the crown is erupted and consequently, due to the great length and size of the reserve crown and roots, extraction of these teeth is a major undertaking. Canine teeth have

a wide pulp cavity that in young adult horses may extend to within 5 mm of the occlusal surface; consequently, the reduction (grinding down) of canines in horses (usually for non-scientifically validated reasons) risks causing pulpar exposure.

1st premolar ('wolf tooth')

One or both of the upper 05s (1st premolar), and less commonly, the lower 05s, can be present as the small, vestigial 'wolf teeth'. These should normally lie immediately in front of the 06s. They are simple brachydont teeth whose clinical crown can vary from 1 to 2 cm in length. Their roots can vary from being non-existent (with loose attachments of the teeth to the gingiva), to being > 30 mm in length. These teeth are sometimes rostrally or rostrolaterally displaced and also may be angulated (i.e., not vertically aligned in relation to the hard palate). The (permanent) 05s usually erupt at 6–12 months of age, and they do not have a deciduous precursor. Wolf teeth have a reported prevalence of 24.4% in females and 14.9% in males;⁶⁰ and of 13%²⁰ to 31.9%⁶¹ in horses of both sexes. This wide range of prevalence is likely due to loss of some wolf teeth at circa 2.5 years of age, when the adjacent deciduous 06s are shed (J. Easley, personal communications).

Cheek teeth

The 12 temporary premolars (506–508, 606–608, 706–708 and 806–808) are erupted at birth or do so within a week or so. These deciduous teeth are replaced by the larger, permanent premolars at circa 2.5, 3, and 4 years of age for the 06s, 07s and 08s, respectively. In contrast to brachydont teeth and to equine incisors (where the deciduous teeth are much smaller than the permanent teeth) the transverse (cross sectional) area of equine deciduous cheek teeth can be similar to those of adult teeth,⁴³ and thus a retained remnant of a deciduous cheek tooth remnant ('cap') can be difficult to identify from the underlying permanent tooth. The three deciduous cheek teeth in each row have a distinct neck between the crown and roots, unlike their permanent successors.⁶² Latterly, these deciduous cheek teeth erupt into the oral cavity due to traction by their periodontal ligaments and pressure from the underlying permanent tooth. They are simultaneously resorbed at their apices by immunologically-mediated mechanisms until eventually just a thin 'cap' of the temporary tooth remains lying on the occlusal aspect of the permanent cheek tooth (Fig. 5.18).

An adult equine mouth normally contains 24 cheek teeth (06s–11s, i.e., 2nd – 4th premolars and 1st – 3rd molars), forming four rows of six teeth that are accommodated in the maxillary and mandibular bones. The molars erupt at approximately 1, 2, and 3.5 years of age, respectively. On transverse section, equine cheek teeth are rectangular shaped, except the first (06) and last (11), which are somewhat triangular shaped (Figs 5.14, 5.34). The maxillary cheek teeth are about 50% wider and so are squarer in comparison with the mandibular cheek teeth, which are narrower and more rectangular in outline. The long axes of all cheek teeth are relatively vertical, except the first cheek tooth (06) whose clinical crown tilts caudally (reserve crown tilts rostrally) and the last cheek tooth (11) and to a lesser and variable extent



Fig. 5.34 Occlusal view of the five maxillary cheek teeth of a 3-year-old horse. Note the absence of spaces between these teeth, the pronounced vertical ridges on the buccal aspects of these teeth, and the triangular shape of the 06s (as will be the case for the 11s when they erupt).

the (10), whose clinical crowns tilt rostrally (reserve crowns tilt caudally; Fig. 5.33). The purpose of these angulations is to compress all six cheek teeth together at the occlusal surface to prevent the development of diastemata. The buccal aspects of the upper cheek teeth have two prominent vertical (longitudinal) ridges (**cingula**, **styles**) rostrally and a less prominent caudal ridge with two deep grooves between them, except the 06s which can have 3–4 small grooves and ridges. These ridges can decrease with age; they vary in size between individual horses and different breeds. Dental overgrowths (enamel 'points') can often be sharp and prominent on the lateral and medial aspects of these occlusal ridges (especially on larger ridges such as 10s and 11s), even in horses on a permanent forage diet. In contrast, horses with less prominent vertical ridges appear to be less likely to develop enamel overgrowths on their maxillary cheek teeth. The palatal aspect of the upper, and both lingual and buccal aspects of the mandibular cheek teeth contain much less distinct vertical grooves and ridges.

In younger horses, the permanent cheek teeth possess long crowns, most of which is un-erupted reserve crown, that are embedded in deep alveoli (Figs 5.18, 5.19, 5.35). In Thoroughbreds, the 06 cheek tooth is the shortest (circa 5–6 cm maximum length), with the remaining cheek teeth being up to 9 cm long at eruption. Dental eruption proceeds throughout the life of equine teeth, and normally the eruption rate corresponds with tooth wear (attrition) and has been calculated as 2–3 mm per year;^{4,5} therefore a 75-mm long permanent 08 cheek tooth that comes into wear at 4 years of age should be fully worn by 30 years of age.⁴

Once their roots have clearly developed (circa 2 years following eruption), the upper cheek teeth usually have three roots, two small lateral roots and a large, flat medial root, but occasionally the medial root will form two separate roots giving a total of four roots.⁶³ The lower cheek teeth (except the 11s, which have three roots) usually have two equally sized roots, one rostral and one caudal, that tend to become longer than those of their maxillary counterparts.

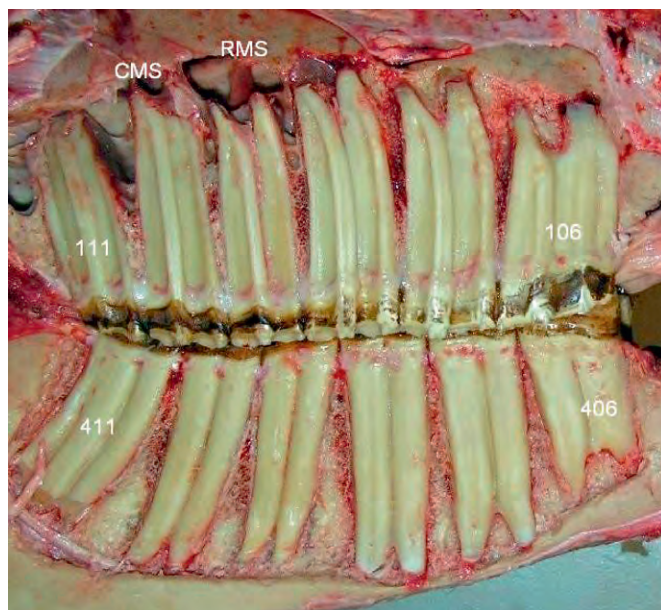


Fig. 5.35 Skull of young horse (circa 7 years) with the lateral maxillary and mandibular walls removed to expose the cheek teeth. Note the long reserve crowns – with the mandibular 408 tooth almost touching the ventral cortex of the mandible. The rostral maxillary sinus (RMS) and caudal maxillary sinus (CMS) overlie the apical aspects of 408–411. Note the angulation of the reserve crowns that keeps the occlusal surface of all 6 teeth tightly compressed together. Root development is present in all teeth. Image courtesy of Istvan Gere.

The alveoli of the first two upper cheek teeth (06s and 07s) and often the rostral aspect of the 08, and usually all of this tooth in older horses⁶² are embedded in the maxillary bone (Fig. 5.18). The caudal aspect of the 08 and the 09 alveoli usually lie in the rostral maxillary sinus, and the alveoli of the 10s and 11s usually lie in the caudal maxillary sinus (Fig. 5.19). However, there can be much variation in this finding, with the rostral aspect of the rostral maxillary sinus varying in position from overlying the 07s to the 09s, and the shell-like, bony transverse maxillary septum (separating the rostral and caudal maxillary sinuses) varying in position from the caudal aspect of the 08s to the caudal aspect of the 09s.^{64,65} In young horses, the alveoli of the large cheek teeth reserve crowns occupy much of these maxillary sinuses, but with age and subsequent eruption of their reserve crowns and remodelling and retraction of their alveoli, the sinus cavities increase in volume, as their floor lowers due to cheek teeth eruption (Fig. 5.36). In younger horses, the infraorbital canal lies directly over the apices of the caudal maxillary cheek teeth, and is often curved dorsally at this site, whereas in the older horse a thin plate of bone (that divides the sinuses sagittally) attaches the alveoli to the infraorbital canal.

Additionally, the cheek teeth migrate rostrally in the sinuses as they erupt.⁵ For example, the apex of the curved upper 11s (caudal maxillary cheek tooth) drifts rostrally from its site beneath the orbit in the young adult, to become sited rostral to the orbit in the aged horse. The intimate relation between the caudal cheek teeth and sinuses can allow periapical infections of the caudal cheek teeth to cause maxillary sinus empyema, as discussed in Chapters 13 (imaging) and 14 (ancillary techniques). The rostral maxillary teeth are

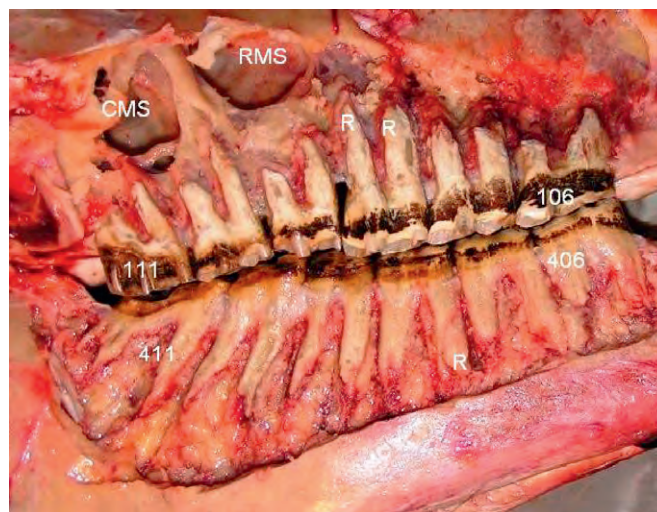


Fig. 5.36 Skull of an aged horse with the lateral maxillary and mandibular walls removed to expose the cheek teeth. Minimal reserve crowns now remain, with most teeth just having alveolar attachment to their (cemental) roots (R) that are very elongated in all teeth. The mandibular teeth in particular still have good angulation of their remnants, that is compressing their occlusal aspects together. There is a 'step-like' overgrowth of the caudal three mandibular cheek teeth. Note the larger rostral maxillary sinus (RMS) and caudal maxillary sinus (CMS) in this older skull as compared to the skull in Fig. 5.35. (Image courtesy of Istvan Gere.)

embedded in maxillary bones: for example, in young Thoroughbreds, the apices of the 08s often lie 2–3 cm rostral to the rostral aspect of the facial crest, the 07s lie 2–3 cm rostral to this site, and the apices of the 06s lie a further 2–3 cm rostrally. In many young horses, eruption cysts occur at these sites during dental eruption, but due to the presence of the overlying levator nasolabialis and levator labii superioris muscles, these swellings may not be detected.

The six maxillary and six mandibular cheek teeth form slightly curved rows (more pronounced in the maxillary cheek teeth), with their concavity facing buccally (laterally) and lingually (medially), respectively.⁵² This convex curvature of the lateral aspect of the maxillary cheek teeth can be marked in some horses and a practical consequence is that it renders effective dental rasping impossible, unless a selection of angulated rasps are available. A common feature of all ungulates (mammals with hooves), including horses, is the presence of an interdental space ('bars of mouth') between the incisors and the premolars, that is likely due to the evolutionary increase in face length (dolicephalic) to allow these long-legged animals to more comfortably graze off the ground⁶⁶ whilst being able to view potential predators. Its presence, however, necessitates the clinical crown of the rostral cheek tooth (06) facing caudally to help compress the occlusal aspect of each row of cheek teeth, as noted earlier (Fig. 5.33). In contrast, the complete arch of teeth of omnivores and many carnivores needs to be compressed in just a single direction with the rostrally (mesially) facing caudal tooth ('wisdom tooth') to promote compression of teeth.⁶⁶

Continued eruption of the angulated rostral and caudal cheek teeth usually maintains the tight occlusal contact between the six cheek teeth until late in life in normal horses,

despite the fact that equine teeth slightly taper in towards their apex and so, with age, would otherwise develop spaces between the teeth (interdentally–interproximally) that is termed diastema(ta) (Fig. 5.25).^{67,68} Many very old horses (>20 years) do develop diastemata between their incisors, which is usually of little consequence in these teeth, unlike the situation with cheek teeth, where diastemata can cause food to accumulate between the teeth and in the adjacent periodontal space, possibly leading to severe dental disease,⁶⁵ and this situation is even more pronounced where cheek teeth diastemata are widespread and cause severe clinical disease.⁶⁹

The occlusal surfaces of the rows of cheek teeth are not level in the longitudinal plane as occurs in some other species, but instead the surfaces of the caudal 2–3 cheek teeth curve dorsally to a variable degree in the caudal direction that is termed the **Curve of Spee** 6 (Fig. 5.33). This curvature is often marked in Arabian-type horse breeds that often have a similar curvature on their (dished) facial bones, but can also be marked in other breeds of horses, even in larger draught horses with convex faces (i.e., ‘rams head’ or ‘Roman nose’). Some horses also have a marked upward curvature of the rostral aspect of their cheek teeth rows, with the lower 06 becoming quite tall (dominant) and little clinical crown present on the upper 06s. This anatomical configuration is likely to be a normal anatomical variation in such horses, that causes no clinical problems, whereas misguided attempts to create a standard appearance of equine teeth certainly can have deleterious clinical consequences. If both a Curve of Spee and a rostral curvature are present, this gives the lower cheek teeth row occlusal surface a concave appearance in the rostrocaudal plane, i.e., raised at the 06s and the 11s.

In normal horses, the distance between the maxillary cheek teeth rows is approximately 23% wider than the distance between the mandibular rows,⁷⁰ a feature which is termed **anisognathia**. Anisognathia is even more marked (27% difference between upper and lower CT) in donkeys.¹⁰ This is in contrast to many brachydont arcades, such as human upper and lower dental arcades, that are equally spaced (isognathic). As noted, the maxillary cheek teeth are also wider than their lower counterparts. Consequently, when the equine mouth is closed, approximately one-third of the occlusal surface of the upper cheek teeth is in contact with about half of the lower cheek teeth’s occlusal surface. Additionally, the occlusal surfaces of the cheek teeth are not level in the transverse (bucco-lingual) plane as is usually the case in brachydont species, but are angled between 15 and 35 degrees [angled from dorsal on their lingual (buccal) aspect to ventral on their buccal aspect] (Figs 5.18 & 5.19). The maxillary cheek teeth have a lower angulation than the mandibular cheek teeth, varying from circa 19.2 degrees at the 06s and decreasing to 9.2 degrees at the 11s. In contrast, the mandibular cheek teeth occlusal angulation increases from 15.3 degrees on the 06s to up to 31.5 degrees on the 11s.⁷¹ Cheek teeth angulation is also influenced by masticatory activity.⁵⁰ For example, on a normal forage diet where horses have a wide range of lateral masticatory movement, the angle is believed to remain within the normal range. In contrast, on a diet high in concentrates, e.g., processed grains, or with an intercurrent painful dental disorder that causes pain on mastication, the masticatory action will be

more vertical and lead to a higher degree of occlusal surface angulation (e.g., >45 degrees in the caudal mandibular cheek teeth), which is termed **shear mouth** if severe.

The terminology concerning the irregularities present on the occlusal surface of the cheek teeth can be confusing. A **cusp** is a pronounced elevation on the occlusal surface of a cheek tooth and is an area with thicker enamel. A **ridge** (or **style**) is a linear elevation on the surface (peripheral or occlusal) of a tooth, and on the occlusal surface may be formed by interconnecting cusps. Horses usually have about 12 such ridges running transversely across the occlusal surface of their cheek teeth that are commonly termed **transverse ridges**, two on the occlusal surface of each tooth, except the first and last, which can contain one to three ridges. These ridges can be quite tall, especially over the caudal cheek teeth in younger horses of certain breeds. Diet and age may also influence their size. These normal anatomical structures that increase the masticatory surface (and efficiency) of cheek teeth should not be confused with narrower acquired transverse overgrowths (usually just a lesser number) often termed ‘exaggerated or accentuated transverse ridges’ due, for example, to being opposite a wide diastema or some other area of reduced contact with their occlusal counterpart.

Because equine cusps contain sharp ridges of exposed occlusal enamel adjacent to hollows (craters) of dentin (and cementum at some sites) they are classified as **lophs** and thus the cusp pattern of equine teeth is termed **lophodont**. A **fossa** is a rounded depression, and a **fissure** is a linear depression between cusps or ridges.^{1,71} The latter physiological fissures should be distinguished from pathological fissure fractures (cracks) in cheek teeth²⁴ that can lead to pulpar exposure.^{25,26} The opposing ridges and (physiological) fissures of the upper and lower equine cheek teeth interdigitate when the mouth is shut. Other variations in cusp number, size and distribution are used for paleontological research and for taxonomic classification of different species.⁷¹

Nerve supply of teeth

Because of its great importance in human dentistry, the innervation of teeth has been well studied in brachydont teeth. Pulpar nerves enter through the apical foramen and include sensory nerves derived from the trigeminal (5th cranial) nerve, which are most extensive in the coronal (occlusal) region of the pulp where they form the plexus of Raschkow,¹³ and sympathetic fibers from the cervical ganglion that supply the vascular smooth muscles to regulate blood flow in the pulp.^{72,73} The latter are also believed to control the differentiation and function of odontoblasts, including their circadian rhythm of activity.³⁰

The type and duration of pain caused by stimulation of dentin are different from those of pulp. In brachydont teeth, dentin responds to various stimuli, including excessive heat and cold, and to therapeutic procedures, such as drilling, with a sharp pain which stops when these stimuli cease. In contrast, stimulation of the pulpal nerves produces dull pain (sometimes a throbbing pain synchronous with the heartbeat caused by the effect of arterial pulsations within the inflamed pulp) which continues for some time after the stimulus is removed.³⁰ Nerves are also present in the pulp of hypsodont teeth, although the role of

sensory nerves is unclear, as these teeth have dentin, including open dentinal tubules, and odontoblast processes constantly exposed on the occlusal surface,³⁸ a situation that would cause marked pain in brachydont teeth. Following significant dental overgrowth reductions, some horses do not masticate properly for days to weeks, and this is without any evidence, attributed to temporomandibular joint (TMJ) pain caused by prolonged opening of the mouth with a speculum during the dental procedures. However, the recent work showing exposed, apparently viable dentinal processes following dental rasping³⁷ makes it more likely that in fact pain from damaged sensitive dentin, or in some cases from actual pulp exposure, is the cause of such post-treatment pain.⁷⁴

Blood supply of teeth

In brachydont teeth, the blood vessels enter pulp through the apical foramen and form an extensive capillary network, particularly in the coronal region of the pulp.³⁰ These capillaries drain into an extensive venous network that has a more tortuous course than the arterioles and also exits via the apical foramen.³⁰ Due to difficulties in microscopically distinguishing lymphatics from vascular capillaries it remains unclear if lymph vessels are actually present in pulp.³⁰ However, other authors believe that pulp tissues (like all other connective tissues), contain lymph vessels that in human beings drain into the submandibular and deep cervical lymph nodes. As previously noted, the good blood supply and wide apical foramina of even adult equine teeth can allow them to retain a blood supply following pulpar exposure and then allow them to seal off the exposed pulp with tertiary dentin. Although not involved in dental blood supply, the greater palatine artery can be iatrogenically damaged during dental procedures and awareness of its site and size is necessary. This artery runs around the periphery of the hard palate and is not an end-artery as it adjoins its counterpart rostrally and thus receives a blood supply from both internal maxillary arteries. It can be damaged if a dental elevator slips medially when extracting wolf teeth, especially if they are medially displaced. It can also be damaged when orally extracting maxillary cheek teeth – which usually have short erupted crowns on their medial (palatal) aspect – if the extraction forceps is placed too high on the gingiva above these teeth.

Supporting bones and muscles of prehension and mastication

Alveolar bone

Alveolar bone is very flexible and constantly remodels to accommodate the changing shape and size of the dental structures it contains. Alveolar bone can be divided into two main parts: a thin layer of compact (radiodense) bone (the 'cortex' of alveolus) that lines the alveolus proper, in which Sharpey's fibers insert, that is radiographically termed the **lamina dura (lamina dura denta)**. This area is radiographically detectable (but not on computed tomography) as a thin radiodense line in brachydont teeth but due to irregularities of the periphery of some normal equine cheek teeth, this feature is not always obvious on lateral radiographs of equine teeth (Fig. 5.37). Secondly, the main alveolar bone surrounding the lamina dura denta cannot be morphologically differentiated from the main bone of the mandible or maxilla in adult brachydont teeth.¹ However, recent studies have shown that in horses, the alveolar bone beneath the lamina dura remains spongy and porous throughout life – similar to the alveolar bone of developing children's teeth – probably a reflection of its constant remodeling as the equine teeth constantly erupt.² This presents an area of anatomical weakness, which may explain why sequestration of the alveolar cortical bone can occur following oral extraction of cheek teeth. The most prominent aspect of the alveolar bone beneath the gingival margin (occlusally) is termed the **alveolar crest**.

Mandible

The mandible, the largest bone of the equine face, is composed of two component hemimandibles that fuse together at the symphysis at 2–3 months of age.⁵¹ The mandible articulates with the squamous temporal bone at the TMJ and contains the alveoli of the mandibular incisors; canines; wolf teeth (if present) and lower cheek teeth. The ventral border of the horizontal ramus of the mandible is wide and rounded in the young horse because of the length and size of the reserve crowns of the cheek teeth it contains (Figs 5.18 & 5.19) and, conversely, becomes thinner and sharper in older horses as the cheek teeth erupt – a feature used to age horses in some Eastern countries. Some breeds, especially those that

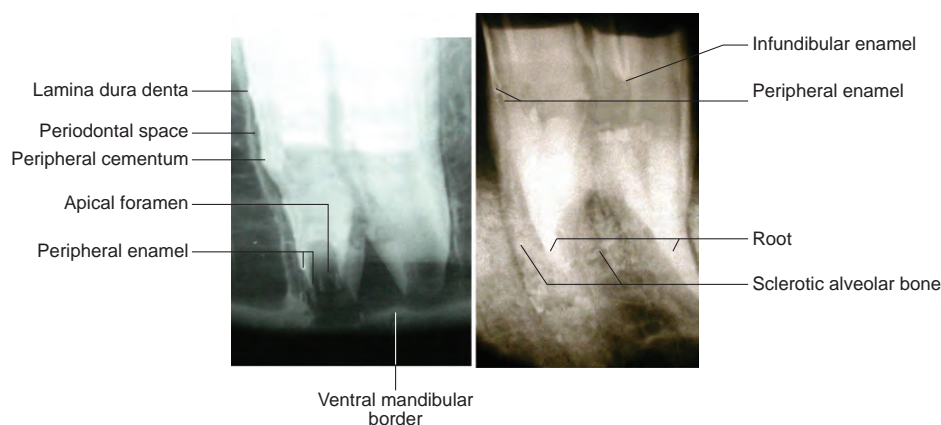


Fig. 5.37 Radiographs of the apical aspects of a young mandibular (left) and an inverted aged maxillary cheek tooth (right). Note the wide periodontal space of the younger tooth that merges with soft tissue of the apical area and into the large apical foramen (of such younger teeth) and on into wide pulp cavities. The peripheral enamel folds reach to the apex of this tooth i.e., it has no enamel-free apical area or true roots. In contrast, the older tooth (right) has long true roots composed of cementum with no radiographically obvious apical foramen or pulp horns. The peripheral (and infundibular enamel) folds are positioned high above the alveolus on this old tooth due to prolonged root cementum deposition.

are descendants of the Arabian horse (which in turn are descendants of *Equus cracoviensis* – Type IV horse), have shallow mandibles and maxillae and commensurately short reserve crowns, whereas most other breeds, e.g., derived from *E. muniensis* (Types I or Mountain Pony) or *E. mosbachensis* (Type III – Forest or Marshland Horse) such as the North European Draught and native British pony types (such as Exmoor ponies) have deep alveoli and long reserve crowns.^{75,76}

It has been proposed that crosses between these two types of horses can develop pronounced ventral swellings under the developing apices of the 2nd and 3rd cheek teeth,⁷⁵ due to an imbalance between mandibular depth and tooth length. These mandibular eruption cysts ('osseous tubercles') (Fig. 5.33) usually occur at 3–5 years of age and exceptionally, unless they become infected (usually by blood borne mechanisms, i.e., anachoresis), they usually regress over the following 1–2 years.⁴³ Other authors suggest that some breeds of horses are predisposed to retention of deciduous cheek teeth remnants ('caps'), which causes these mandibular swellings,⁶⁷ but clinical studies have not verified this.⁷⁷

The mental nerve (branch of Cranial Nerve V) enters the mandibular foramen on the medial aspect of the vertical ramus, level with the occlusal surface of the cheek teeth. The mental nerve can be locally anesthetized at the mandibular foramen to facilitate painful dental procedures (e.g., oral extraction of a mandibular tooth) in the standing horse. The nerve then continues rostroventrally in the mandibular canal until it reaches the ventral aspect of the horizontal ramus, where it then continues rostrally within the mandible below the apices of the cheek teeth. However, in recently erupted teeth whose apices reach the ventral border of the mandible, the nerve usually lies on the medial aspect of the developing tooth (Fig. 5.18). The main part of the mental nerve emerges through the mental foramen on the rostrolateral aspect of the horizontal ramus, approximately halfway between the lower 06 and the incisors, while a smaller branch continues rostrally in a smaller canal along with the vasculature of the lower incisors. The nerve supply to the lower incisors and lower canine tooth can be anesthetized within the rostral aspect of the mandibular canal.

Immediately caudal to the alveoli of the lower 11s (6th cheek teeth), the mandible becomes a very thin sheet of bone. This flattened, thin area progressively increases in size with eruption of the caudal mandibular cheek teeth and subsequent contraction of their alveoli. More caudally, at the angle of the jaw, this thin plate of bone expands medially and laterally into two thick bony protrusions that are roughened to allow muscle attachment (Fig. 5.33). These protrusions reduce in size towards the dorsal border of the vertical ramus. These normal roughened mandibular areas may be radiologically confused with pathological mandibular changes.

TMJ and muscles of mastication

In contrast to carnivores that have a **vertical power stroke**, horses also have a transverse power stroke in a lingual (medial) direction that is termed a **lingual power stroke**,⁷⁸ as described in detail in Chapter 6 (physiology) and consequently, their masseter and medial pterygoideus muscles are

their most highly developed masticatory muscles and are innervated (like most muscles of mastication) by the mandibular branch of the 5th cranial nerve. The facial (7th) nerve just innervates the superficial facial muscles (i.e., muscles of expression). The powerful masseter muscle originates along the full length of the facial crest and zygomatic arch and has wide insertions along the caudo-lateral aspect of the mandible, with its deeper fibers running ventrocaudally and its more superficial fibers running almost vertically. Its elevated rostral border is caudal to the site where the facial artery, facial vein and parotid duct cross the ventral border of the mandible and ascend vertically. In horses, the TMJ lies circa 15 cm above the level of the cheek teeth occlusal surface, and thus the movement arm of the masseter is longer. The powerful pterygoideus medialis and lateralis muscles lie on the medial aspect of the mandible, and have similar attachments and orientation to the masseter, and can move the jaw sideways almost continually with a strong power stroke.⁵ In some horses the pterygoideus muscles are larger than the more obvious masseters. The relatively small digastricus muscle, which attaches from the occipital bone to the caudal aspect of the mandible, functions to open the mouth – a gravity-assisted process that takes little mechanical effort, hence the small muscle size. Horses can generate massive occlusal pressure (up to 875N during the power stroke) during mastication, that is highest between the caudal cheek teeth, i.e., closest to the fulcrum (TMJ).⁷⁹ Further details on masticatory function and on the TMJ are presented in Chapter 6 (physiology) and Chapter 23 (TMJ).

The articular extremities of the mandible are composed of the condyle that lies caudally and the coronoid process, rostrally. The latter is poorly developed in the horse (Fig. 5.33) because it has smaller temporalis muscles (which close the jaw) compared to carnivores, where the power stroke of the jaws is vertical (to catch and crush prey), consequently both the temporalis muscle and coronoid process are larger in carnivores. Between the articular surfaces of the mandible and the squamous temporal bone lies an articular disc that divides the TMJ cavity in two. The joint capsule is tight and reinforced by an indistinct lateral ligament, and an elastic posterior ligament.⁵¹

Although it allows just limited opening of the jaws, the equine TMJ has a wide range of lateral movements to permit the cheek teeth to effectively grind coarse foodstuffs, utilizing a side to side movement that is combined with a slight rostrocaudal movement of the TMJ, with one side gliding rostrally and the other caudally. This rostrocaudal movement can vary greatly between horses and can be demonstrated in some sedated horses by gentle pushing and pulling of the mandible rostrocaudally relative to the TMJ. More clinically significantly, this rostrocaudal mandibular movement can be demonstrated by closing the mouth and then elevating the head – which causes caudal movement of the mandible relative to the maxilla. Lowering the head causes the opposite (rostral) mandibular movement. This maneuver can cause a horse with mild overjet to have normal occlusion on lowering the head. Horses with large focal dental overgrowths may have restriction of their rostrocaudal mandibular movement – but due to individual variation between horses this parameter is difficult to quantify.

Maxillary bones

The upper jaws are largely formed by the paired maxillary bones that contain the alveoli of the upper cheek teeth, wolf teeth and canine teeth (if present). The relationship of the cheek teeth to the maxillary bones and maxillary sinuses has been discussed earlier. As noted, the rostral maxillary area in younger horses may become focally swollen because of the presence of the underlying eruption cysts of the 06s–08s. The overlying bone may become thin and distended, with a temporary and even focal loss of bone over the developing apices occurring, but as noted these features are usually masked by the overlying muscles. Some 3–4-year-old equids (mainly ponies) develop marked bilateral firm swellings of the rostral maxillary bones during eruption of these teeth, giving their face a 'box-like' appearance. These are the equivalent of the mandibular eruption cysts ('osseous tubercles', '3 or 4-year-old bumps') of this same age group.

The facial crest is a lateral protrusion of the maxilla that continues caudally as the zygomatic process and then joins the zygomatic parts of the malar and temporal bones to form the zygomatic arch (Fig. 5.33). After giving off a small branch that runs rostrally to innervate the maxillary incisor teeth, the infraorbital nerve (a sensory branch of cranial nerve V) emerges through the infraorbital foramen, circa 5 cm dorsal to the rostral aspect of the facial crest. Its point of exit is covered by the pencil-like levator labii superioris muscle, that can be dorsally displaced to allow local anesthesia of this nerve within the canal to anesthetise the upper 06 (possibly the 07), wolf teeth, canines, and incisors.

The dorsal and caudal borders of the maxillary bone are attached to the nasal and lacrimal bones respectively, whilst rostrally, the maxillary bone is attached to the premaxilla (incisive bone). The thicker ventral border of the maxillary bones contains the alveoli. The individual cheek teeth alveoli are fully separated by transverse, inter-alveolar bony septa. As noted, the equine maxillary sinuses are uniquely divided into rostral and caudal compartments by a thin, transversely angulated bony septum that can vary greatly in position. The medial aspect of each maxillary bone forms a horizontal bony shelf (the palatine process) that joins mid-line with its opposite counterpart to form the supporting bone of most of the hard palate; the remainder of the hard palate is supported by similar flat bony extensions, caudally by the palatine bone, and rostrally by the premaxilla (incisive bone).

Premaxillary (incisive) bone

The paired premaxillary (incisive) bones form the rostral aspect of the upper jaw. Their thick rostral aspects contain the alveoli of the incisors, whilst their thinner caudal aspects form the rostral aspect of the hard palate. The almost transverse suture line between the premaxillae and maxillae is an anatomically weak site that is a common site of fractures, especially in young horses. The canine teeth (if present) lie on the maxillary side of this suture.

Oral mucosa

The mucosa of the gingiva and hard palate is a specialized masticatory mucosa. It can be **keratinized**, **orthokeratinized** or **parakeratinized** and has deep interdigitating rete pegs extending into the underlying vascular, subcutaneous

connective tissue that limit its mobility. Most of the gingiva is firmly attached to the supporting bone, with a slightly more mobile (usually non-keratinized) area, termed the free (marginal) gingiva, which is the prominent area close to the tooth. Between the free gingiva and the tooth lies a depression termed the **gingival sulcus**, which is lined by non-keratinized epithelium. In the deepest area of the gingival sulcus lies the junctional epithelium, which is attached to the peripheral cementum of the tooth, with the periodontal ligament lying directly below this layer. In the horse, with its prolonged dental eruption, this area is constantly remodeling and reforming new periodontal ligaments and new gingival-dental attachments. In other species, interdental papillae of gingiva are present between teeth to prevent food trapping and subsequent periodontal disease, but as noted, most equine teeth are tightly compressed at the occlusal surface and so have no interproximal spaces occlusally.

The salivary glands

The (paired) main equine salivary glands are the parotid, mandibular, and sublingual glands whose ducts drain directly into the mouth. Minor salivary glandular tissue is also present in the lips, tongue, palate, and buccal regions. The largest salivary gland is the parotid, which is circa 20–25 cm long, 2–3 cm thick, and weighs circa 200g in Thoroughbreds, producing up to 50 ml of saliva/min. This salivary gland lies behind the horizontal ramus of the mandible, ventral to the base of the ear, rostral to the wing of atlas, extending ventrally just caudal to the mandible as far as the tendon of origin of the sternomandibularis muscle and the external maxillary vein (Fig. 5.38).^{5,51} The lateral aspect of the parotid salivary gland is usually level with the masseter muscle, except for a small flat area of this salivary gland which can protrude above the surface of the masseter muscle at the level of the lateral canthus of the eye, and which often overlies some of the parotid lymph nodes at this site. In some apparently normal horses, the parotid salivary gland may swell and protrude 1–3 cm above the masseter muscle level when they are turned out to grass, in the ill-defined condition termed idiopathic parotitis (colloquially termed 'grass glands').

The jugular vein is often embedded in the parotid salivary gland and the medial aspect of this gland covers the stylohyoid bone, carotid artery, facial nerve, guttural pouch and the origins of the brachiocephalicus and sternocephalicus muscles – the latter separating the parotid and mandibular salivary glands.⁵ The dorsal aspect of the parotid salivary gland contains lymphatic tissue within its substance or lying beneath it, which can become focally distended following purulent infections (especially strangles) of that region. The parotid duct originates from an amalgamation of 3–4 large ducts that converge on the rostroventral aspect of the parotid gland and this large duct then initially runs on the medial aspect of the pterygoideus muscles (and mandible), and then crosses beneath the ventral aspect of the mandible, just caudal to the facial artery and vein. The parotid duct then moves dorsally on the lateral aspect of the mandible, moving rostral to the accompanying vasculature, and it perforates the cheek at the level of the upper 08s³⁵ (Fig. 5.38). At its caudal sites, the parotid duct is vulnerable to injury during cheek teeth repulsion, whilst it can be damaged more

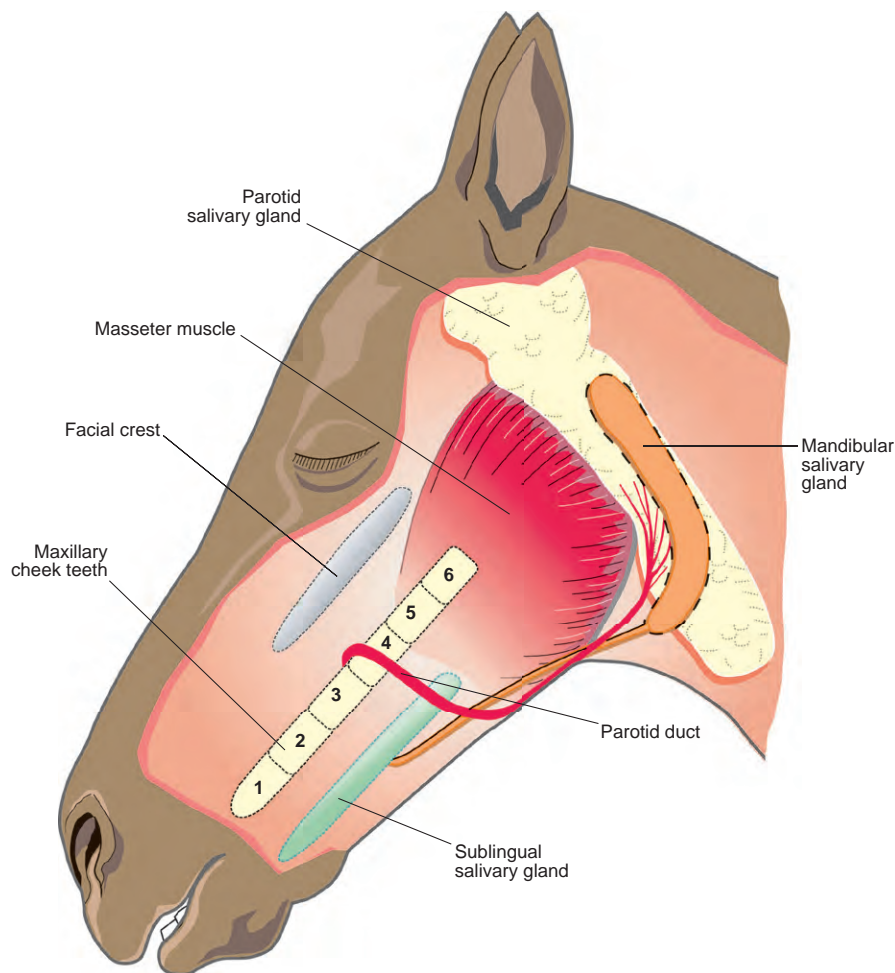


Fig. 5.38 Diagram outlining the three (paired) equine salivary glands.

rostrally by cheek teeth extraction by the lateral buccotomy technique.⁸⁰

The smaller, (20–25 cm long and 2–3 cm wide, circa 50 g weight in adult medium-sized horses) mandibular salivary gland lies deep to the mandible and parotid salivary glands and so is not palpable. It curves around beneath the parotid salivary gland and mandible, extending from the base of the atlas as far ventrally as the basihyoid bone. Its duct arises on its concave aspect and travels almost the full length of

the oral cavity in the sublingual fold, running beside the sublingual salivary glands rostrally, and enters into the oral cavity on the lateral aspect of the sublingual caruncle.⁵ The long, thin sublingual salivary glands lie superficially in the floor of the mouth beneath the sublingual fold of the oral mucosa. They lie between the tongue and mandible, extending from the mandibular symphysis to the level of the lower 09 and then drain through multiple small ducts into the oral cavity.⁵¹

References

1. Berkovitz BKB, Moxham B. Development of dentition: early stages of tooth development. In: Dental Anatomy and Embryology. Osborn JW, ed. Blackwell Scientific, Oxford, 1981, pp 166–174
2. Mitchell SR, Kempson SA, Dixon PM. Structure of peripheral cementum of normal equine cheek teeth. *Journal of Veterinary Dentistry* 2003; 20: 199–208
3. Butler P. Dentition in function. In: Dental anatomy and embryology. Osborn JW, ed. Blackwell Scientific, Oxford, 1991, p. 345
4. Baker GJ. Oral examination and diagnosis: management of oral diseases. In: Veterinary dentistry. Harvey CE, ed. WB Saunders, Philadelphia, 1985, pp 217–228
5. Dyce KM, Sack WO, Wensing CJC. Textbook of veterinary anatomy. WB Saunders, Philadelphia, 1987, pp 473–477
6. Easley J. Equine dental development and anatomy. In: In-Depth Dentistry Seminar. Proceedings of the American Association of Equine Practitioners 1996; 42: 1–10
7. DeLahunta A, Habel RE. Applied veterinary anatomy. WB Saunders, Philadelphia, 1986, pp 4–16
8. Miles AEW, Grigson C. Colyer's variations and diseases of the teeth of animals, revised edition. Cambridge University Press, Cambridge, 1990, pp 2–15, 482
9. Kirkland KD, Baker GJ, Marretta SM, et al. Effect of ageing on the endodontic system reserve crown and roots of equine mandibular cheek teeth. *American Journal of Veterinary Research* 1996; 57: 31–38

10. du Toit N, Kempson SA, Dixon PM. Donkey dental anatomy. Part 1: Gross and computed axial tomography examinations. *The Veterinary Journal* 2008; 176: 338–344
11. Warshawsky H. The teeth. In: Weiss L, ed. *Histology*, 5th edn. Macmillan Press, New York, 1983, pp 609–655
12. Fortelius M. Ungulate cheek teeth: developmental functional and evolutionary interrelations. *Acta Zoologica Fennica* 1985; 180: 1–76
13. Ten Cate AR. Development of the tooth and its supporting tissues; hard tissue formation and its destruction; dentinogenesis. In: Ten Cate AR, ed. *Oral histology*, 4th edn. CV Mosby, St Louis, 1994, pp 58–80, 111–119, 147–168
14. Kollar EJ, Lumsden AGS. Tooth morphology: the role of innervation during induction and pattern formation. *The Journal of Biological Buccale* 1979; 7: 49–60
15. Brescia NJ. Development and growth of the teeth. In: Sicker H, ed. *Orban's Oral Histology and Embryology*, 6th edn. CV Mosby, London, 1966, pp 18–37
16. Latshaw WK. Face mouth and pharynx. In: Latshaw WK, ed. *Veterinary developmental anatomy – a clinically oriented approach*. BC Decker, Toronto, 1987
17. Ferguson M. The dentition throughout life. In: Elderton RJ, ed. *The Dentition and Dental Care*, vol 3. Heinemann, Oxford, 1990, pp 1–18
18. Suga SJ. Comparative histology of progressive mineralisation patterns of developing incisor enamel of rodents. *The Journal of Dental Research* 1979; 58: 1025–1026
19. Eisenmann DR. Amelogenesis; enamel structure. In: Ten Cate AR, ed. *Oral histology*, 4th edn. Ed CV Mosby, St Louis, 1994, pp 218–256
20. Baker GJ. A study of dental disease in the horse, PhD Thesis. Glasgow University, 1979, pp 3–96
21. Fitzgibbons C, du Toit N, Dixon PM. Anatomical studies of equine cheek teeth infundibulae. *Equine Veterinary Journal* 2010; 42: 37–43
22. Kilic S, Dixon PM, Kempson SA. A light and ultrastructural examination of calcified dental tissues of horses: 4 Cement and the amelo-cemental junction. *Equine Veterinary Journal* 1997; 29: 213–219
23. Kilic S, Dixon PM, Kempson SA. A light and ultrastructural examination of calcified dental tissues of horses: 2 Ultrastructural enamel findings. *Equine Veterinary Journal* 1997; 29: 198–205
24. Simhofer H, Griss R, Zetner K. The use of oral endoscopy for detection of cheek teeth abnormalities in 300 horses. *The Veterinary Journal* 2008; 178: 396–404
25. Dacre IT, Kempson SA, Dixon PM. Pathological studies of cheek teeth apical infections in the horse: 4: Aetiopathological findings in 41 apically infected mandibular cheek teeth. *The Veterinary Journal* 2008; 178: 341–351
26. Dacre IT, Kempson SA, Dixon PM. Pathological studies of cheek teeth apical infections in the horse 5: Aetiopathological findings in 57 apically infected maxillary cheek teeth and histological and ultrastructural findings. *The Veterinary Journal* 2008; 178: 352–363
27. du Toit N, Kempson SA, Dixon PM. Donkey dental anatomy Part 1: Histological and scanning electron microscopy examinations. *The Veterinary Journal* 2008; 176: 345–353
28. Shellis P. Dental tissue. In: Osborn JW, ed. *Dental anatomy and embryology*. Blackwell Scientific, Oxford, 1981, pp 193–209
29. Stanley HR, White CL, McCray L. The rate of tertiary reparative dentine formation in the human tooth. *Oral Surgery, Oral Medicine and Oral Pathology* 1966; 21: 180–189
30. Nanci A. The pulp-dentin complex. In: Nanci A, ed. *Ten Cate's Oral Histology: Development Structure and Function*, 7th edn. Mosby, Elsevier, 2007, pp 191–238
31. Magloire H, Joffe A, Bleicher F. An in vitro model of human dental pulp repair. *Journal of Dental Research* 1996; 75: 1971–1978
32. Dacre IT, Kempson SA, Dixon PM. Pathological studies of cheek teeth apical infections in the horse 1: Normal endodontic anatomy and dentinal structure of equine cheek teeth. *The Veterinary Journal* 2008; 178: 311–320
33. Fawcett DW. *A textbook of histology*. WB Saunders, Philadelphia, 1987, pp 603–618
34. White C, Dixon PM. A study of the thickness of cheek teeth subocclusal secondary dentine in horses of different ages. *Equine Veterinary Journal* 2010, in press
35. Muylle S, Simoens P, Lauwers H. A study of the ultrastructure and staining characteristics of the 'dental star' of equine incisors. *Equine Veterinary Journal* 2002; 34: 230–234
36. Kilic S, Dixon PM, Kempson SA. A light and ultrastructural examination of calcified dental tissues of horses: 3 Dentine. *Equine Veterinary Journal* 1997; 29: 206–212
37. Kempson SA, Davidson M, Dacre IT. The effects of three types of rasps on the occlusal surface of equine cheek teeth: a scanning electron microscopic study. *Journal of Veterinary Dentistry* 2003; 20: 19–27
38. Kilic S, Dixon PM, Kempson SA. A light and ultrastructural examination of calcified dental tissues of horses: 1 The occlusal surface and enamel thickness. *Equine Veterinary Journal* 1997; 29: 206–212
39. Muylle S, Simoens P, Lauwers H. Tubular contents of equine dentin: a scanning electron microscopic study. *Journal of Veterinary Medicine Series A* 2000; 47: 321–330
40. Holland GR. Morphological features of dentin and pulp related to dentin sensitivity. *Archives of Oral Biology* 1994; 39: supplement, 3–11
41. Dacre I. A pathological study of equine dental disorders PhD Thesis. University of Edinburgh, Edinburgh, 2005
42. Dacre IT. Equine dental pathology. In: Baker GJ, Easley J, eds. *Equine Dentistry*, 2nd edn. Saunders, Philadelphia, 2005, pp 91–110
43. Dixon PM, Copeland AN. The radiological appearance of mandibular cheek teeth in ponies of different ages. *Equine Veterinary Education* 1993; 5: 317–323
44. Warhonowicz M, Staszuk C, Rohn K, Gasse H. The equine periodontium as a continuously remodeling system: morphometrical analysis of cell proliferation. *Archives of Oral Biology* 2006; 51: 1141–1149
45. Staszuk C, Gasse H. Primary culture of fibroblasts and cementoblasts of the equine periodontium. *Research Veterinary Science* 2007; 82: 150–157
46. Jones SJ. Human tissue: cement. In: Osborn JW, ed. *Dental anatomy and embryology*. Blackwell Scientific, Oxford, 1981, pp 193–209
47. Capper SR. The effects of feed types on ingestive behaviour in different horse types, BSc Thesis. University of Edinburgh, Edinburgh, 1992
48. Myers JS. The effects of body size grass height and time of day on the foraging behaviour of horses, MSc Thesis. Aberystwyth University, Aberystwyth, 1994, p. 56
49. Leue G. Zahne. In: Dobberstein J, Pallaske G, Stunzi H, eds. *Handbuch der speziellen pathologischen Anatomie der Haustiere*, 3rd edn. Verlag Paul Parey, Berlin, 1941, pp 131–132
50. Bonin SJ, Clayton HM, Lanovaz JL, Johnston T. Comparison of mandibular motion in horses chewing hay and pellets. *Equine Veterinary Journal* 2007; 39: 258–262
51. Sisson S, Grossman JD. Splanchnology. In: *The anatomy of domestic animals*, 4th edn. WB Saunders, Philadelphia, 1953, pp 406–407
52. Walmsley JP. Some observations on the value of ageing 5–7 year-old horses by examination of their incisor teeth. *Equine Veterinary Education* 1993; 5: 195–298
53. Richardson JD, Lane JG, Waldron KR. Is dentition an accurate indication of the age of a horse? *Veterinary Record* 1994; 137: 88–90
54. St Clair LE. Teeth. In: Getty R, ed. *Sisson and Grossman's the Anatomy of the Domestic Animals*, Vol 1, 5th edn. WB Saunders, 1975, pp 460–470

55. Floyd MR. The modified Triadan system nomenclature for veterinary dentistry. *Journal of Veterinary Dentistry* 1991; 8: 18–20
56. Goody PC. Horse anatomy. JA Allen, London, 1983, pp 38–41
57. Eisenmenger E, Zetner K. Veterinary dentistry. Lea, Febiger, Philadelphia, 1985, pp 55–57, 153–157
58. Mueller POE. Equine dental disorders: cause diagnosis and treatment. *The Compendium of Continuing Education* 1991; 13: 1451–1460
59. du Toit N. An anatomical pathological and clinical study of donkey cheek teeth, PhD thesis. University of Edinburgh, Edinburgh, 2008, p. 416
60. Colyer JF. Variations and diseases of teeth of horses. *Transactions of the Odontological Society of Great Britain New Series* 1906; 38: 47–74
61. Wafa NSY. A study of dental disease in the horse, MVM Thesis. University College, Dublin, 1988, pp 1–203
62. Huidekoper RS. Age of domestic animals. FA Davis, Philadelphia and London, 1891, pp 33–35
63. Bradley OC. The topographical anatomy of the head and neck of the horse. W Green, Edinburgh, 1923, pp 85–92
64. Perkins J. Quantitative and qualitative anatomy of the equine maxillary sinuses with particular reference to the nasomaxillary aperture, MScThesis, University of Edinburgh, Edinburgh, 2001
65. Tremaine WH, Dixon PM. Equine sinonasal disorders: a long term study of 277 cases Part I. Historical clinical and ancillary diagnostic findings. *Equine Veterinary Journal* 2001; 33: 274–282
66. Osborn H. Cement. In: Sicker H, ed. *Orban's Oral histology and embryology*, 6th edn. CV Mosby, London, 1966, pp 155–212
67. Dixon PM. Dental extraction in horses: Indications and preoperative evaluation. *Compendium of Continuing Education for the Equine Practitioner* 1997; 19: 366–375
68. Dixon PM, Tremaine WH, McGorum BC, et al. Equine dental disease – a long term study of 400 cases part 2: disorders of development eruption and variations in position of the cheek teeth. *Equine Veterinary Journal* 1999; 31: 519–528
69. du Toit N, Burden FA, Dixon PM. Post mortem survey in 349 donkeys from an aged population 2005–2006. Part 1: prevalence of specific dental disorders. *Equine Veterinary Journal* 2008; 40: 204–208
70. Taylor AC. An investigation of mandibular width and related dental disorders in the equine oral cavity, thesis. Coventry University, Coventry, 2008
71. Kilic S. A light and electron microscopic study of the calcified dental tissues in normal horses. PhD Thesis. University of Edinburgh, Edinburgh, 1995
72. Hayward AF. Human tissue: Pulp. In: Osborn JW, ed. *Dental anatomy and embryology*. Blackwell Scientific, Oxford, 1981, pp 187–190
73. Torneck CD. Dentine-pulp complex. In: Ten Cate AR, ed. *Oral Histology* 4th edn. Mosby, St Louis, 1994, pp 169–213
74. Dixon PM. The gross histological and ultrastructural anatomy of equine teeth and their relationship to disease. *Proceedings of the 49th Annual Convention of the American Association of Equine Practitioners* 2002; 48: 421–424
75. Speed JG. Horses and their teeth. *The Journal of the Royal Army Veterinary Corps* 1951; 22: 136–141
76. Copeland AN. 1990, unpublished observations
77. Dixon PM, Tremaine WH, McGorum BC, et al. Equine dental disease – a long term study of 400 cases: Part 4 – Apical infections of the cheek teeth. *Equine Veterinary Journal* 2000; 32: 182–194
78. Tremaine WH. Dental care in horses. *Practice Journal of Veterinary Postgraduate Clinical Study* 1997; 19(1): 86–199
79. Staszuk C, Lehmann F, Bienert A, et al. Measurement of masticatory forces in the horse. *Pferdeheilkunde* 2006; 22: 12–16
80. Dixon PM, Gerard M. Oral cavity and salivary glands. In: Auer G, Stick JA, eds. *Equine surgery*, 3rd edn. Elsevier, St Louis, 2008, pp 321–350

Dental physiology

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Introduction

This chapter focuses on how the masticatory system manages ingested feed and prepares it for digestion. There is a large amount of published data on the effect of chewing in the ruminant and other herbivorous species.¹ In the former case, fermentation within the rumen does not significantly reduce particle size, and in the horse there is no significant reduction in ingesta particle size between stomach and anus, leaving mastication as the most important determinant in feed particle size reduction.

The morphology of equid teeth and their role in effectiveness of mastication have not been widely studied. Human studies have used molar occlusal surface area (OSA) as an indicator of chewing effectiveness. The influence of this variable on a variety of nutritional parameters has been studied in red deer,² where researchers found that animals with low OSA had a greater mean fecal particle size, but no difference in the mean retention time of gastrointestinal contents was found between groups. Additionally, animals in the low OSA group had a greater mean number of chews per gram of dry matter than high OSA animals.

Because the primary masticatory movement of herbivorous animals is a lateral translocation of the mandible, the enamel ridge perimeter distance (termed 'length of occlusal enamel edge', ERPD) has been used to assess mastication in some studies. This measurement has been used in studies of Nubian ibex, red deer, possums, gliders, koalas, and horses.²⁻⁷ In koalas, ERPD was found to be directly related to chewing effectiveness.⁶

Only recently has similar attention turned to studies of dental physiology and masticatory biomechanics of the horse. This revival has been driven by the fact that a greater number of horses are currently undergoing oral examinations on a routine basis, the findings of which are querying the etiopathogenesis of common dental malocclusions. The absence of dental malocclusions or dental abnormalities should, in theory, result in a normal masticatory cycle, which would generate the appropriate forces on the occlusal surfaces of teeth for effective mastication, as well as resulting in sufficient even wear of the entire occlusal surfaces of all teeth, thus preventing overgrowth. However, the patterns of jaw movement (masticatory biomechanics) are the result of a complex interrelationship between food consistency, particle size, and neural control of mastication.⁸

Functional morphology

Thomas Henry Huxley, an ardent evolutionist, gave a public lecture in New York City on September 22 1876 entitled 'The demonstrative evidence of evolution' in which he used, as his subject matter, the evolution of the horse beginning with Eohippus (now termed *Hyracotherium*).^{9,10} This lecture was given in support of the newly published work, *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life* by Charles Darwin.

The evolution of the modern horse (*Equus caballus*) from its Eocene ancestors was one of the first examples recognized to support the work of Charles Darwin. Two remarkable adaptive traits allowed the horse to take advantage of increasing areas of grassland: a rapid (by paleobiological standards) change in dental morphology in just over 1.5 million years (or 0.5 million generations) and secondly, the loss of extraneous digits in the support of a single, enlarged middle toe adapted for speed.

The basic mammalian dental formula is of 3 incisors, a canine, 4 premolars and 3 molar teeth. The significance of the cheek tooth arrangement is two-fold. Firstly, premolars have a deciduous (juvenile) counterpart, and secondly, they are generally smaller and less robust than the larger, permanent molars. Thus, the importance of the molarization (or the assimilation of molar tooth characteristics) of the 2nd – 4th equine premolars should not be underestimated. In the modern horse, the first premolar is vestigial and is the only cheek tooth not to have evolved hypsodonty and a complex root system in conjunction with the remaining teeth.

The environmental drive forcing the ancestors of the horse from browsing to grazing and to develop a greater body size, selected individuals with a different dentition than previously required. Grasses are high in abrasive silicates, which, in addition to Cope's Law (stating that within a lineage there is a tendency or trend toward increasing body size), forced an increase in body size from the fox-terrier-sized Eohippus (estimated to be 3 hands, i.e., 12 inches tall ≈5 kg) to the modern 14–16 hand (56–68 inch tall, 500–1000 kg) horse. A doubling of body mass requires an eight-fold increase in the amount of ingested feed. Simply doubling the size of teeth would result in only a 4-fold increase in the surface area of the occlusal surface of the tooth, which would be inadequate to support these evolutionary changes.

Thus, evolutionary strategies to overcome these problems included an increase in the relative size of each tooth, a change in the type and complication of the relationship between dentin and enamel ridges, and an increase in crown height (hypsodonty). There was even a lineage (clade) of late Miocene horses (*Pseudhipparion*) that developed hypselodont (elodont) teeth (continually growing teeth, like those of rodents), but these horses were ultimately unsuccessful.

Ancestors to *Eohippus* (*Phenacodus*) had premolar and molar teeth formed like those of the pig or bear.¹¹ They were broad and bore many separate conical cusps on the occlusal surface that evolved to deal with a varied diet of insects, fruits or vegetables. As with the modern horse, the lower teeth were narrower than the uppers; however, the surface variations were such that both sets of teeth meshed together when the jaws were closed. Microscopic wear patterns on these teeth have suggested that the predominant chewing motion was crushing (vertical), rather than the modern shearing (side-to-side) action.¹² In *Hyracotherium* the anterior (towards the front) premolars of the upper jaw were still shaped as cutting blades and were triangular. The complete row of cheek teeth in this animal was no more than 10 cm in length in a mesial-distal (rostrocaudal) direction, approximately the same length as two cheek teeth of the modern *Equus caballus*.

A later horse, *Orohippus*, developed a sub-triangular-shaped second premolar (from its initial cutting blade appearance), but the fourth premolar was already four-cusped and quadrate (square). *Epihippus* had a squarer second premolar, but both the third and fourth premolars were now quadrate. The outer crest of the tooth (the ectoloph) became W-shaped at this stage and has remained so since. *Mesohippus* emerges at 40 million years, and all teeth except the first premolar are now molarized with the exception of the first premolar, which (if present) remains a unicuspid tooth to the present day.

Thus molarization, the first defining moment in equine dental evolution, was complete within 20 million years. However, these teeth were still brachydont (low crowned) and not able to withstand the rigors of animals wholly committed to grazing. Hypsodonty did not make a determined appearance in the fossil record until the evolution of *Parahippus* (23 million years) and its descendent *Merychippus*, at which time the predominant chewing direction was side-to-side with a wide stroke action ensuring efficient shearing forces applied over the chewing surface.¹³ Interestingly, research also indicates a gradual increase in crown height from *Parahippus* through *Merychippus* into the modern equine lineage and also into the extinct *Hipparion* group of horses.¹⁴

Enamel crests became increasingly convoluted, with the effect of increasing the surface area (or perimeter) of the enamel. These changes were similar in both upper and lower jaws, but the changes were less extreme in the lower teeth.¹⁵ The spaces between enamel ridges are filled by a softer material (dentin) which is preferentially worn away to create craters rimmed by sharp enamel edges over which the grass is sheared. In conjunction with the infolding (pleating) of enamel ridges, cementum appeared in late *Parahippus* and *Merychippus* animals.¹⁶ This material is softer than enamel but is firm, tough and less brittle. Cementum filled the areas around the edges of the brittle enamel crests providing

support, which otherwise would have resulted in breakage of the enamel crests and thus negation of the hypsodont effect. Cement is also formed within the enamel infoldings (infundibula) of the maxillary cheek teeth as the teeth develop within the dental sac. Cement is also produced around the developing roots as they are formed. In this way, a cheek tooth with prolonged eruption is formed with a crown height (including reserve height) of at least twice its width. Such a tooth usually erupts at a rate equal to the rate of the wear of the crown by attrition; however, in some cases, where there is no opposing tooth, 'super-eruption' may occur.

Odontological evolution in the horse was thus a rapid, sustained event encompassing the molarization of premolar teeth, the development of hypsodonty and cemental protection, as well as amalgamation of enamel crests into linear occlusal ridges to increase efficacy for shearing coarse forage. These evolutionary advantages are thought to have allowed the horse to advance from a generalized browsing animal to a specialized grazer, thus enabling it to take advantage of the increasing grassland areas of the late Eocene, Oligocene, and Miocene eras. By the time of the arrival of *Merychippus* and the subsequent radiation (encompassing 19 species in the late Miocene), the dental revolution was effectively at an end. Some small variations in the degree of hypsodonty continued, notably in the form of *Nannohippus*; however, the dental pattern observed in the modern horse (*Equus caballus*) is essentially unchanged for 15 million years. (See Chapter 1 for more detail.)

Anatomy

Molarization of the cheek teeth of the horse, as with most herbivores, resulted in a row of 6 cheek teeth (not including the 1st premolar), which function as a single chewing unit. The integrity of this unit is maintained due to a combination of the initial caudal angulation of the clinical crown of premolars 2 (Triadan 06) and to a variable extent of the 07 and the rostral (mesial) angulation of the clinical crowns of molars 1 to 3 (Triadan 09–11), the 'keystone effect' of an almost vertical eruption of the 4th premolar (08, Fig. 6.1)

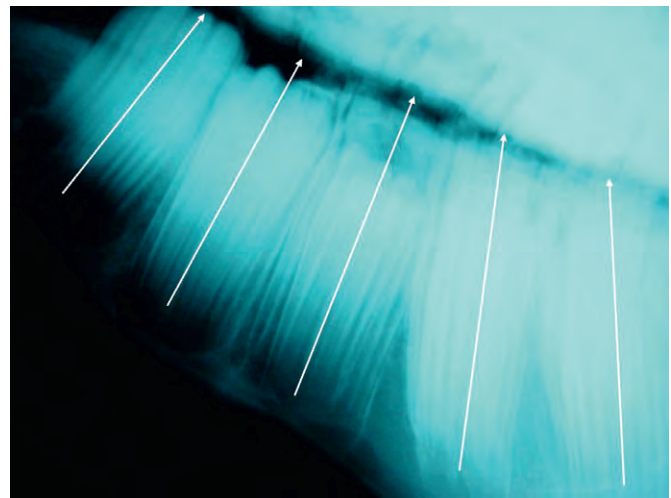


Fig. 6.1 A lateral radiograph of a young horse (4 years old) showing the relative angulation of the cheek teeth (lines).

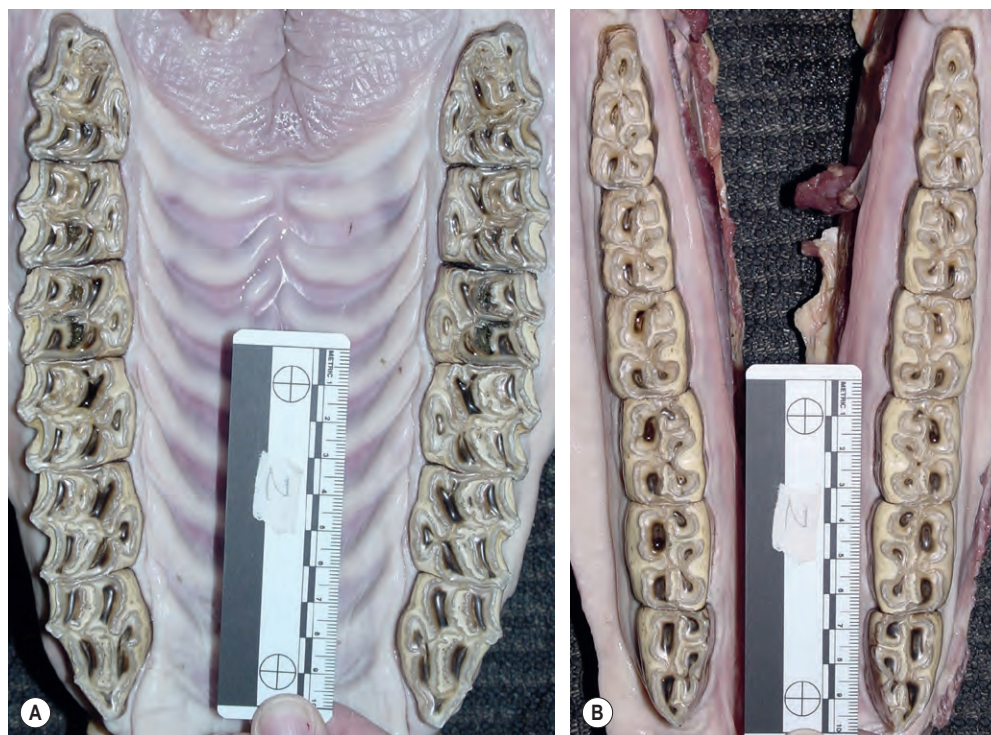


Fig. 6.2 (A) A photograph of an equine maxilla taken post mortem. Note the curvilinear arrangement of the cheek teeth and compare the width of the interdental oral cavity (IDOC) with that of the mandibular teeth. (B) A photograph of an equine mandible taken post mortem. Note the relatively straight arrangement of the cheek teeth and compare the width of the interdental oral cavity with that of the maxilla.

and the rostral (mesial) drift of cheek teeth as the horse ages.

The horse is anisognathic, i.e., the lower dental arcade is straighter and 23–30% narrower than that of the upper arcade (Fig. 6.2), such that the maxillary teeth project laterally beyond the mandibular teeth (Fig. 6.3). There is a significant difference in morphology between maxillary and mandibular cheek teeth, with the former generally having a greater surface area and containing more enamel in the form of mesial and distal infundibula.¹⁷ Despite large differences in body weight realized by *Equus caballus*, measurements of total cheek tooth enamel ridge perimeter distance have been found to be only 7 cm more in a 1000 kg horse when compared with a 350 kg pony.¹⁸ More recently, a number of dental morphological variables (including total, inner, and outer enamel ridge perimeter distance as well as total, inner, and outer surface area) were measured in horses of different body size and further confirmed an absence of correlation between body size and any measured variables.⁷

The mandible articulates with the maxilla at the temporomandibular joint (TMJ). This is a synovial joint formed by the condylar processes of the mandible and the articular tubercle of the temporal bone. The relative incongruity between these bones is accommodated by the presence of a fibrocartilagenous disc. The joint capsule is reinforced by the presence of rostral and caudal ligaments, the latter of which is concurrently attached to the disc. The joint is divided by the disc into a larger dorsal and a smaller ventral compartment, which communicate on the axial aspect of the joint. TMJ morphology has been described in-depth using a variety of different imaging modalities,^{19,20–22} (and as described in Ch. 23) and while the relative shapes and sizes of the osseous components vary with the size of the head, there is a consistent angulation of the mandibular condyle and temporal

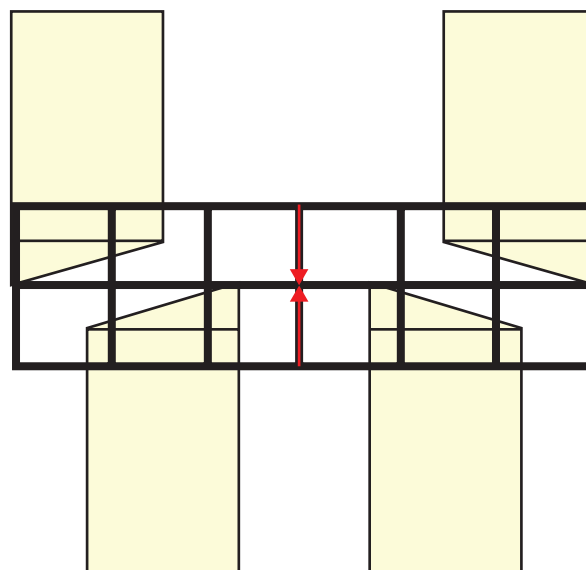


Fig. 6.3 A schematic diagram of the equine head as it pertains to the teeth. The outline of the incisors is in black and the position of the cheek teeth can be seen through them. Note that in centric occlusion (when interdental spaces 1/201 and 3/401, red arrows, are in alignment) the cheek teeth are not in occlusion. This is normal.

bone. The mandibular condyles are angled at approximately 15°, in a ventromedial to dorsolateral plane as well as from a mediocaudal to laterorostral direction (Fig. 6.4). These angles are mirrored by those of the articular portion of the temporal bone. Interestingly, this 15° angulation of the TMJ is also reported to be reflected in cheek tooth occlusal angles, as well as the angles of the palatine ridges.²³ More recent

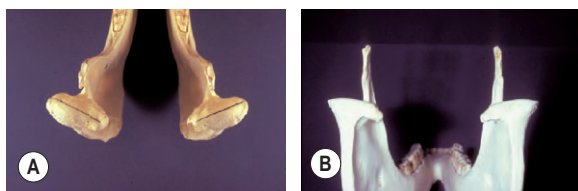


Fig. 6.4 (A) Mandibular condyles, caudal view -15° angles. (B) Mandibular condyles, dorsal view -15° angles.

studies do not support this association as closely. Cadaver studies suggested that not all cheek teeth within an arcade have the same angulation.^{24,25} Mean angulation in the former study was 10° (± 6 degrees SD) and was unaffected by tooth position or tooth age,²⁴ whereas in the latter study mandibular angles ranged from 19.2 to 30° and were significantly different from their maxillary counterparts, with a range from 12.5 to 18° .²⁵ In a study using live horses, mean molar cheek tooth occlusal angle was determined to be 9° (± 2 degrees) and 10.6 degrees ($\pm 7^\circ$) using a photographic and single tooth method, respectively.²⁶

Jaw closing is effected primarily by the paired masseter and temporalis muscles with a contribution from the pterygoid muscles. These muscles originate on the maxilla and cranium and insert on the mandible.

Jaw opening is effected by contraction of the anterior belly of digastricus combined with the contraction of geniohyoideus, and the inferior fibers of genioglossus coupled with the sternohyoideus and omohyoideus. All of these muscles that open and close the jaw are innervated by the fifth cranial (trigeminal) nerve.

The significant disparity in mass between jaw elevator and depressor musculature can be explained by understanding the movements of the equine jaw during prehension and mastication. The mandible is elevated (mouth closed) against resistance (gravity and feed), whereas opening is primarily effected by gravity. Prehended feed is crushed and sheared during jaw closure, which requires forces exceeding those generated simply by elevating the mass of the mandibular structures. Jaw muscles have faster contraction rates than most other striated muscles, with reported contraction rates of 333–500 cycles/min in pygmy goats.²⁷

The muscles of the cheeks and lips include the levator and depressor labii maxillaris and mandibularis, the orbicularis oris, the incisivus mandibularis and maxillaris, the buccinator and zygomaticus muscles. These muscles are innervated by the seventh cranial (facial) nerve and control lip closure, elevation, retraction and depression, as well as the flattening of the cheeks.

The role of dentition in post-masticatory feed digestibility in the horse has been extensively studied in recent years. Three initial clinical trials examined the role of dentition in equine nutrition.^{28–30} The former two pronounced a benefit of dental floating on feed digestibility, whereas the latter did not. Further studies suggest that although occlusal equilibration (floating) increases the rostrocaudal mobility (RCM) of the mandible,³¹ and reduces the number of chews/kg DM (hay and barley) it does not alter chew rate,³² or improve feed digestibility, fecal particle size, or weight gain in the pregnant mare.^{31,33,34} Examination of the control animal subset similarly did not find a correlation between oral pathology score and weight gain.

There is also controversy surrounding the effect cheek tooth occlusal angle and cheek tooth occlusion percentage have on crude protein and fiber digestion,^{30,35} with others finding no discernable effect on the same outcome variables.²⁶ Additionally, the study of Carmalt and Allan found no correlation between any dental morphological variable examined and feed digestibility or ingesta particle size.⁷

Mastication: the chewing cycle

Chewing is a repetitive, cyclical motion resulting from the contraction of musculature. Other than in man, studies of chewing cycles in mammals indicate consistent chewing patterns (individually and within the species). How the food is broken down, however, in horses, depends on the integrity of the cheek teeth. In the following description of the masticatory cycle, the start-point will be the 'neutral position', when the incisors are in centric occlusion (i.e., the interdental space of 1/201 and 3/401 are in vertical alignment, Fig. 6.3) and the cheek teeth are not in occlusion. Other methods of description use maximal incisor separation as the start-point.³⁶

Herbivorous mammals have a masticatory cycle consisting of three phases: the opening stroke (O), the closing stroke (C), and the power stroke (P), which are defined by the relative displacement of the mandible.³⁷ Using isolated frames from a video recording of equine mastication (Fig. 6.5A), a schematic diagram of mandibular motion was constructed (Fig. 6.5B). Note that Points 1–4 represent the opening stroke, including a small but integral rostral movement of the mandible.^{31,38} Points 5–6 represent the closing stroke, and Points 7–10 represent the power stroke. This analysis of the equine masticatory cycle suggests, in fact, the presence of a fourth stroke – a post power 'recovery' stroke. During the opening stroke, the mandible is displaced (laterally translated) to the point that cheek teeth occlusion occurs, at which point further displacement (translation) necessitates incisor separation (Fig. 6.6). The forces generated during the closing and power equine masticatory strokes have been reported to be $248\text{N} \pm 117\text{N}$ (24.8kg) and $875\text{N} \pm 278\text{N}$ (87.5 kg), respectively. Maximum chewing force recorded was 1758N (175.8 kg).³⁹

Some observers have stated that horses appear to be either right-sided or left-sided chewers. While some horses consistently demonstrate major lateral mandibular excursion to one side only, the belief that they are only applying crushing force to one side of the mouth consistently is not accurate. In a study of the masticatory movements of 400 horses, 45 horses (11%) chewed on both sides, 163 horses (41%) moved the mandible to the right (i.e., clockwise as viewed from the front) and 131 (32%) chewed counterclockwise (i.e., mandibular movement to the left), while 63 horses had incomplete observations recorded.⁴⁰

It has further been suggested that during the power stroke in ungulate mastication, there is only contact with one side of the arcade at a time.^{41,42} This may be the case in some species, but in the horse, the extent of anisognathism would suggest that there has to be some contact with both sides. Despite this anatomical constraint, major pressure would first be applied to one side and then, as the surfaces slide across each other, to the other side (frames 5–10). It might

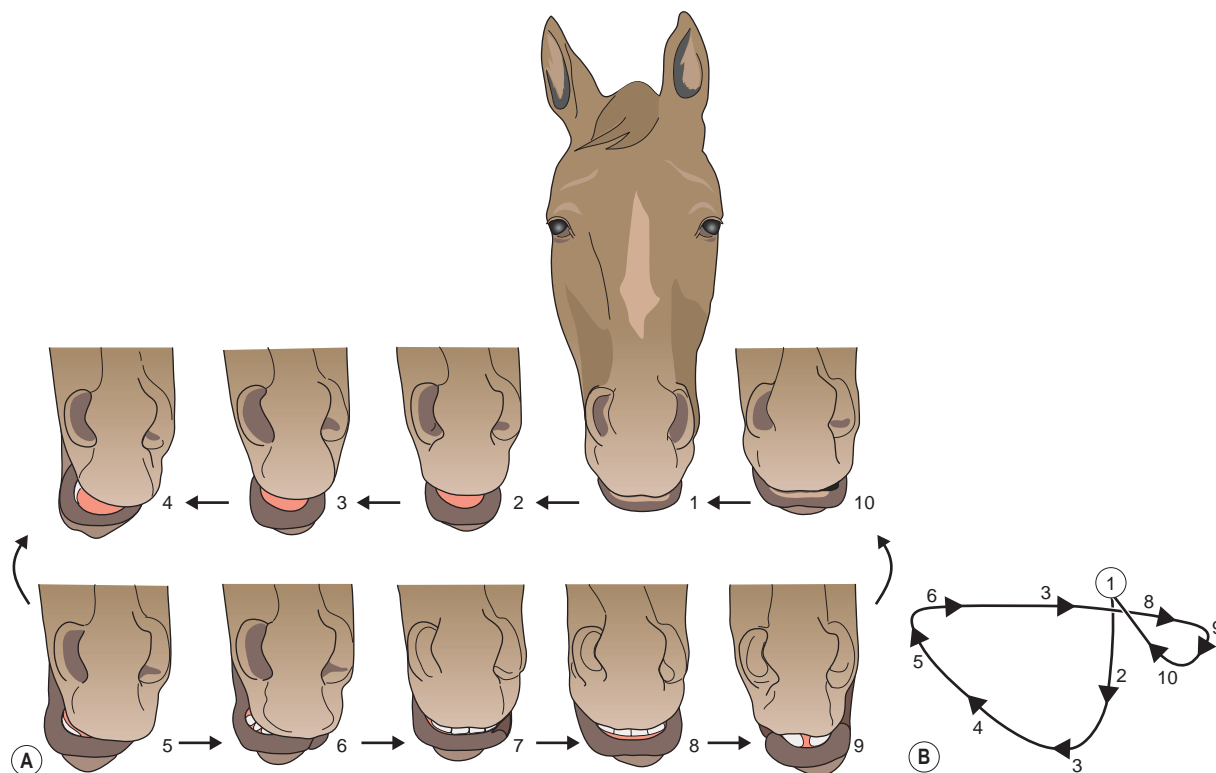


Fig. 6.5 (A) Isolated video frames during a single masticatory cycle in the horse. (B) Schematic diagram to explain mandibular movement during the masticatory (chewing) cycle. The figure is drawn from an imaginary perspective, above and immediately ahead of the horse's head.

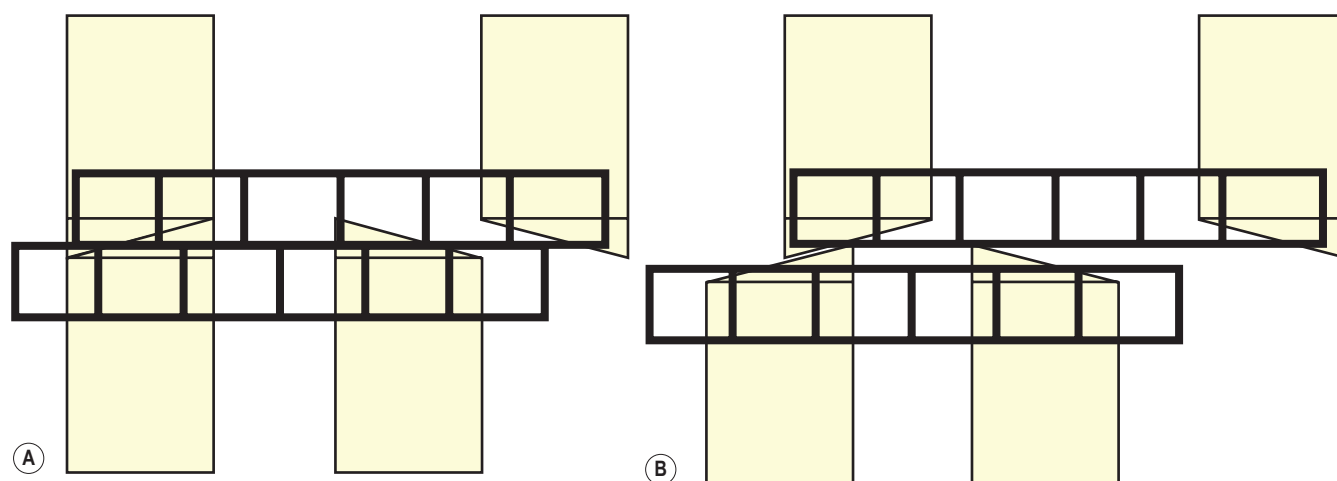


Fig. 6.6 (A) A schematic diagram of the equine head as it pertains to the teeth during the opening cycle of mastication. In this view, the mandibular movement is to the reader's left and is arrested at the point of molar contact. To travel further laterally, incisor separation has to occur. (B) As above. Lateral movement is complete. Cheek teeth are in maximal occlusion, and the incisors are separated.

be concluded from these observations that there is a tendency for unequal dental attrition as a result of the variation in masticatory physiology. Necropsy examination of the occlusal surfaces of the cheek teeth of horses (including those with routine dental care, as well as those with a known history of no dental care) does not support this.

When eating, the horse uses its lips to prehend food material and pull it between the incisor teeth. The incisors cut or grasp the food material using a bite force of approximately 2% of body weight.⁴³ The rostral part of the mouth is thus filled, and mastication begins. The passage of feed across the

occlusal surfaces of the cheek teeth and its subsequent movement caudally within the oral cavity can be likened to that of an auger. It is important to remember at this stage that all six cheek teeth function as a single unit and feed material is processed by each portion of each tooth only once, as the bolus is moved caudally. The cheeks keep the ingested, partially masticated feed within the intradental oral cavity (IDOC).

As the feed material is crushed, it is directed into the IDOC by the food channels on the occlusal surfaces of the cheek teeth (loph basins). There are also 18 pairs of incomplete

Table 6.1 Mean (\pm SD) values for mastication parameters for the four horses used in the food-processing experiment

Mastication parameter	Fiber diet		
	Low	Medium	High
g/'mouthful'	12.1 \pm 2.1	9.5 \pm 2.4	8.1 \pm 1.3
Chew rate/10 s	11.6 \pm 0.6	11.5 \pm 0.2	11.4 \pm 0.2
Energy/g/chew	9.4 \pm 4.8 \forall 10–3	8.9 \pm 6.4 \forall 10–3	1.4 \pm 1.4 \forall 10–2
Duration of grind (s)	0.51 \pm 0.08	0.53 \pm 0.03	0.55 \pm 0.02
Incisor displacement (cm)	4.4 \pm 0.6	4.5 \pm 0.6	4.4 \pm 0.3
Premolar 4 velocity (cm/s)	10.4 \pm 1.8	9.7 \pm 2.4	8.5 \pm 0.4

Collinson (1994)¹⁸ with permission.

palatine ridges, each of which is curved from caudolateral to rostro-medial, and offset in the midline (Fig. 6.2A). Food material is compacted in the IDOC, pressed against the palatine ridges by the tongue and moved caudally by the rotatory action of mastication, tongue and cheek compression. Swallowing is initiated when boluses of food collect in the oropharynx.

The auger analogy has been substantiated by descriptions of feed-bolus shapes obtained from edentate horses. Provided that feed presentation (crushed or soaked) is acceptable, edentate horses can survive and thrive, but if they are allowed access to long-stem fiber (such as grass or hay), spiral boluses of unmasticated feed combined with copious amounts of saliva are produced, which may represent a choke (esophageal obstruction) hazard.⁴⁰

Factors influencing masticatory movements include the fiber and moisture content, and the physical structure (degree of processing) of the diet. Chew rates have been calculated from electromyographic data,³⁷ and direct observations^{18,44} (Table 6.1, data recorded over 10 minutes). It was noted that horses were capable of attaining higher than 11 per second chew rates, particularly at the onset of feeding. In more recent studies, rates of 8 \pm 1 chew cycles per 10 seconds (0.8 cycles per second) have been recorded.³⁹ The degree of lateral excursion was originally documented in an innovative study that produced 'molographs' of the chewing pattern (the extent of lateral excursion) in horses eating different feeds.⁴⁵ However, Collinson's research¹⁸ did not confirm these earlier observations that higher fiber content and lower moisture content reduced the extent of excursion of the mandible.⁴⁵ More recently, studies have documented the three-dimensional kinematics of the equine TMJ and associated movement of the equine mandible during mastication.^{18,46} A further study used the same recording method (using markers attached to the maxilla and mandible) to determine the relative positions of these structures while horses chewed either hay or pellets.⁴⁷ From these data, the three-dimensional position, i.e., displacement and rotation (defined as yaw, pitch, and roll) of the mandible compared to the maxilla could be calculated. There was no difference in mean velocity of mandibular motion between hay and pelleted diets; however, chewing frequency was lower in hay compared to pellet diets. The study also found that there was greater lateral translation (movement) of the mandible

when chewing hay than when chewing pellets. This increased lateral movement was sufficient to allow full occlusal contact between upper and lower cheek teeth rows during the chewing cycle. These scientific data lend support to clinical observations that horses managed extensively may not develop significant cheek tooth malocclusions (specifically sharp lateral edges to the maxillary cheek teeth and lingual edges to their mandibular counterparts) as frequently as pellet fed, intensively managed stabled animals.^{33,48}

Mandibular motion is controlled by the muscular forces acting upon it; however, morphological changes in dentition (occlusal pathology or malocclusions such as a 'shear mouth') or TMJ pathology have the potential to dramatically affect masticatory efficiency. Determining whether TMJ disease leads to alterations in the biomechanical forces during mastication that subsequently cause dental malocclusions, or whether dental malocclusions lead to altered mastication, thereby leading to TMJ pathology, is very difficult. To date, other than cases of septic or traumatic joint disease of the TMJ, there are no published data (clinical case reports or otherwise) to support a diagnosis of degenerative joint disease of the TMJ, despite the fact that it clearly occurs (see Ch. 23).

Summary

The design and function of the equine masticatory apparatus has been refined over millions of years to cope with the feedstuffs necessary for survival. The development of hypsodonty, prolonged eruption of teeth, and the balancing of eruption and attrition have been finely tuned. The masticatory cycle results in balanced dental attrition which, in the absence of dental abnormalities, serves the horse well. The process of domestication (intensive rather than extensive management styles) and the advent of processed feedstuffs significantly alter the duration and biomechanics of mastication. These factors, in combination with increased performance expectations, selective breeding that ignores the presence of inherent dental disorders, and the current longevity of horses, have resulted in the appearance of dental malocclusions and diseases of the soft tissues of the mouth upon which the science and art of equine dentistry are based.

References

- Pérez-Barberia FJ, Gordon IJ. Factors affecting food comminution during chewing in ruminants: a review. *Biological Journal of the Linnean Society* 1998; 6(3): 233–256
- Pérez-Barberia FJ, Gordon I. The influence of molar occlusal surface area on the voluntary intake, digestion, chewing behaviour and diet selection of red deer (*Cervus elaphus*). *J Zool Lond* 1998; 245: 307–316
- Gross J, Demment M, Alkon P, et al. Feeding and chewing behaviors of Nubian ibex- compensation for sex-related differences in body-size. *Funct Ecol* 1995; 9: 385–393
- Gipps J, Sanson G. Mastication and digestion in *Pseudocheirus*. In: Smith AP, Hume ID, eds. *Possums and gliders*. Australian Mammal Society, Sydney, 1984, pp 237–246
- Lanyon JM, Sanson GD. Koala (*Phascolarctos cinereus*) dentition and nutrition. I. Morphology and occlusion of cheek teeth. *J Zool Lond* 1986; 209: 155–168
- Lanyon JM, Sanson GD. Koala (*Phascolarctos cinereus*) dentition and nutrition. II. Implications of tooth wear in nutrition. *J Zool Lond* 1986; 209: 169–181
- Carmalt JL, Allen A. The relationship between cheek tooth occlusal morphology, apparent digestibility, and ingesta particle size in the horse. *J Am Vet Med Assoc* 2008; 223(3): 452–455
- Hiiemae KM. Mammalian mastication: a review of the activity of the jaw muscles and the movements they produce in chewing. In: Butler PM, Joysey KA, eds. *Development, function and evolution of teeth*. Academic Press, London, 1978, pp 359–398
- MacFadden BJ. What's the use? Functional morphology of feeding and locomotion (pp 229–262). In: *Fossil horses. Systematics, paleobiology and evolution of the family equidae*, Cambridge University Press, Cambridge, UK, 1992
- Anon. The theory of evolution. *The New York Times*. September 23rd 1876
- Bennett D. The evolution of the horse. In: Evans JW, ed. *Horse breeding and management*. Elsevier Science, New York, 1992, pp 21–29
- Butler PM. Some functional aspects of molar evolution. *Evolution* 1972; 26: 474–483
- Rensberger JM, Forsten A, Fortelius M. Functional evolution of the cheek tooth pattern and chewing direction in Tertiary horses. *Paleobiology* 1984; 10: 439–452
- Stirton RA. Observations on evolutionary rates in hypsodonty. *Evolution* 1947; 1: 32–41
- Simpson GG. *Horses*. Oxford University Press, Oxford, 1951, pp 106–108
- Stirton RA. Development of characters in horse teeth and the dental nomenclature. *J Mamm* 1941; 22: 339–410
- Carmalt JL, Allen AL. Morphology of the occlusal surfaces of premolar and molar teeth as an indicator of age in the horse. *J Vet Dent* 2008; 25(3): 182–188
- Collinson M. Food processing and digestibility in horses (*Equus caballus*). BSc Dissertation, Monash University, 1994, pp 36–42
- Weller R, Taylor S, Maierl J, et al. Ultrasonographic anatomy of the equine temporomandibular joints. *Equine Vet J* 1999; 31: 529–532
- Rodriguez MJ, Agut A, Gil F, Latorre R. Anatomy of the equine temporomandibular joint: study by gross dissection, vascular injection and section. *Equine Vet J* 2006; 36: 143–147
- May KA, Moll HD, Howard RD, et al. Arthroscopic anatomy of the equine temporomandibular joint. *Vet Surg* 2001; 30: 564–571
- Rodriguez MJ, Latorre R, Lopez-Albors O, et al. Computed tomographic anatomy of the temporomandibular joint in the young horse. *Equine Vet J* 2008; 40: (fast track)
- Baker GJ. Equine temporomandibular joints (TMJ): Morphology, function and clinical disease. In: *Proceedings American Association of Equine Practitioners* 2002; 48: 442–447
- Carmalt JL. Observations of the cheek tooth occlusal angle in the horse. *J Vet Dent* 2004; 21: 70–75
- Brown SL, Arkins S, Shaw DJ, Dixon PM. Occlusal angles of cheek teeth in normal horses and horses with dental disease. *Vet Rec* 2008; 162: 807–810
- Carmalt JL, Townsend HGG, Cymbaluk NJ. The effect of cheek tooth occlusal angle and degree of occlusion on weight gain, feed digestibility and fecal particle size in horses. *J Am Vet Med Assoc* 2005; 227: 110–113.
- Gans C, DeVree F. Correlation of accelerometers with electromyograph in the mastication of pygmy goats (*Capra hircus*). *Anatomical Record* 1974; 306: (Abst): 1342–1343
- Gatta D, Krusic L, Casini L, et al. Influence of corrected teeth on digestibility of two types of diets in pregnant mares. In: *Proceedings 14th Symposium Equine Nutrition and Physiology Society*. 1995, pp 326–331
- Krusic L, Easley J, Pagan JD. Influence of corrected teeth on daily food consumption and glucose availability in horses. In: *Proceedings 1st Symposium on horse diseases*. Radenci, Slovenia, 1995, pp 53–68
- Ralston SL, Foster DL, Divers T, et al. Effect of dental correction on feed digestibility in horses. *Equine Vet J* 2001; 33: 390–393
- Carmalt JL, Townsend HGG, Allen AL. A preliminary study to examine the effect of dental correction on rostro-caudal mobility of the equine mandible. *J Am Vet Med Assoc* 2003; 223: 666–669
- Ellis AD. The effect of dental condition on feed intake behaviour, digestibility of nutrients and faecal particle sizes in horses. In: *Proceedings horse health nutrition: Second European Equine Health & Nutrition Congress*, Equine Research Centre. Waiboerhoeve, Lelystad, Netherlands, 2004
- Carmalt JL, Allen AL. The effect of rostro-caudal mobility of the mandible on feed digestibility and fecal particle size in the horse. *J Am Vet Med Assoc* 2006; 229: 1275–1278
- Carmalt JL, Townsend HGG, et al. The effect of dental floating on weight gain, body condition score, feed digestibility and fecal particle size in the pregnant mare. *J Am Vet Med Assoc* 2004; 225: 1889–1893
- Rucker BA. Modified procedure for incisor reduction. In: *Proceedings 41st Annual Meeting American Association of Equine Practitioners* 1995, pp 41, 42–44
- Hiiemae KM. Mammalian mastication: a review of the activity of the jaw muscles and the movements they produce in chewing. In: Butler PM, Joysey KA, eds. *Development, function and evolution of teeth*. Academic Press, London, 1978, pp 359–398
- Weijs WA, Dantuma R. Electromyography and mechanics of mastication in the albino rat. *Journal of Morphology* 1975; 146: 1–34
- Bonin SJ. Three dimensional kinematics of the equine temporalmandibular joint. MS Thesis, Michigan State University, 2001
- Staszuk C, Lehmann F, Bienert A, et al. Measurement of masticatory forces in the horse. *Pferdeheilkunde* 2006; 22: 12–16
- Baker GJ. *Dental Physiology*. In: *Equine dentistry*, 2nd edn. Baker GJ, Easley J, eds. Elsevier, London, 2005, pp 49–54
- Fortelius M. Ecological aspects of dental functional morphology in the Pleistocene rhinoceroses of Europe. In: Kirsten B, ed. *Teeth, form, function and evolution*. Columbia University Press, New York, 1982, pp 163–181
- Fortelius M. Ungulate cheek teeth: developmental, functional and evolutionary interrelations. *Acta Zoologica Fennica (Helsinki)* 1985; 180: 78
- Hongo A, Akimoto M. The role of incisors in selective grazing by cattle and

- horses. *J Agric Science* 2003; 140: 469–477
44. Brøkner C, Nørgaard P, Søland TM. The effect of grain type and processing on equine chewing time. *Pferdeheilkunde* 2006; 22: 453–460
45. Leue G. Beziehungen zwischen Zahnanomalien und Verdauungsstörungen beim Pferde unter Heranziehung von Kaubildern. *Veterinary Medicine Dissertation*, Hanover, 1941, pp 170–174
46. Bonin SJ, Clayton HM, Lanovaz JL, Johnson TJ. Kinematics of the equine temporomandibular joint. *Am J Vet Res* 2006; 67: 423–428
47. Bonin SJ, Clayton HM, Lanovaz JL, Johnson TJ. Comparison of mandibular motion in horses chewing hay and pellets. *Equine Vet J* 2007; 39: 258–262
48. Carmalt KP, Carmalt JL. Equine dentistry: what do we really know? *J Vet Dent* 2007; 21: 134–135

Aging

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Introduction

The age of a horse can be an important consideration when forecasting its useful working life, when purchasing the animal, for insurance policies and for the prognosis of diseases. Furthermore, as long as no indelible identification methods for horses are imposed, age estimation contributes to the identification of an animal.

Why does the horse, of all animals, have teeth that lend themselves to age determination? Most domestic animals (cattle, carnivores, etc.) have brachydont incisor teeth, i.e., low-crowned teeth that erupt fully prior to maturity and that are strong enough to survive for the life of the animal. Equine teeth, which are subjected to much higher levels of dietary abrasive forces, are hypsodont, which means that they erupt continuously over most of the horse's life. It is important in this context to make a distinction between tooth growth and tooth eruption. Tooth growth implies the lengthening of the tooth in its apical part due to the deposition of new layers of dentin and cement. Tooth eruption is the progressive protrusion of the tooth out of its alveolus. It is now generally assumed that tooth eruption is caused by a continuous remodeling of the periodontal ligament fibers and not by root lengthening as was claimed before. The deposition of bone at the bottom of the alveolus should be the result rather than the cause of tooth eruption.¹

Equine incisors erupt lifelong, whereas their intrinsic growth ceases at the age of about 17.² As the total length of horse incisors remains unchanged from the age of six until the age of 17, the continuous loss of occlusal dental tissue is compensated by an equal amount of newly formed dental tissue at the apical end of the tooth. During this period of time, tooth root growth makes up for occlusal wear, which is estimated to occur at a rate of 2.5 mm a year.³ In horses aged over 17 years, occlusal wear is no longer compensated by apical tooth growth, and the total incisal length diminishes progressively. In horses of this age category, continuous tooth eruption is the only mechanism to provide maintenance of occlusal contact between upper and lower incisors.

Because of the marked wear on the surface of hypsodont equine teeth, occlusal exposure of dentin and cement is inevitable after the protecting enamel is worn off. This leads to the presence of alternate layers of the three calcified tissues

at the occlusal surface, whose continuously changing configuration allows a macroscopic dental age estimation.^{4–15}

The most appropriate teeth for aging horses are the (lower) incisors. The premolars and molars can be used with considerable accuracy to determine the horse's age, but their distal position has limited their use.¹⁶ Recent work has shown that cheek teeth morphology data can be used to predict age in horses that possess all permanent dentition.¹⁷ Radiographic assessment of cheek teeth root morphology can also help in determining age, especially in the young horse.⁸ Because contact between upper and lower canines is seldom made, canines do not wear down in a regular way and have no age-related occlusal surface.

When estimating a horse's age by its incisors, the eruption dates and the changes in appearance of the occlusal surfaces are the main criteria. Neither is wholly dependable but the first is the more reliable, although limited in application to younger animals. The second may be used throughout the life span but becomes increasingly inaccurate with age.¹⁸ Incisival characteristics that are frequently used for dental aging in horses are summarized below.

Eruption

In this context, gingival emergence is used as a reference point for eruption.

Eruption of the deciduous incisors (Fig. 7.1)

The deciduous incisors are smaller than the permanent ones. The surface of their crown is white and presents several small longitudinal ridges and grooves. The occlusal tables of deciduous incisors are oval in the mesiodistal direction.

Eruption of the permanent incisors (Figs 7.2 & 7.3)

Permanent incisor teeth are larger and more rectangular than the deciduous incisors. Their crown surface is largely covered with cement and has a yellowish aspect. The upper incisors generally present two distinct longitudinal grooves on their labial surface; the lower incisors have only one clearly visible groove.



Fig. 7.1 Arabian horse, 2 years old. The deciduous incisors have small ridges and grooves on their labial surface.



Fig. 7.2 Belgian draft horse, 2 years and 10 months. The right permanent central incisor (401) is emerging through the gum. All other incisors are deciduous.



Fig. 7.3 Belgian draft horse, 5 years and 7 months. All incisors are permanent and have a yellowish appearance.

Changes of the occlusal surface (Fig. 7.4)

Appearance of the dental star

The dental star is a yellow-brown structure on the occlusal surface situated between the labial edge of the incisor and the infundibular cavity or 'cup.' It consists of secondary and



Fig. 7.4 Standardbred horse, 8 years old. Dark-colored dental stars are present in all lower incisors. The characteristic white spot in the center of the dental star appears in the centrals (arrows). Cups have disappeared from the central incisors. The remaining marks are oval (arrowheads). Deep cups are still present on the middle and the corner incisors.

tertiary dentin that occludes the pulpal chamber when it risks being exposed by wear. In young animals the dental star appears as a linear stripe because the occlusal end of the original pulp cavity is not conical but elongated in a mesio-distal direction. With age dental stars become oval and then round and move towards the center of the occlusal table. These progressive patterns reflect cross-sections through the stuffed pulp cavity at various levels.

Disappearance of the cups

The infundibulum is an enamel infolding in the occlusal surface of the equine incisor. The superficial half of the infundibulum is empty or filled with food particles. This part is called the 'cup.' The bottom of the infundibulum is filled with cement. When wear has brought this infundibular cement layer into the occlusal surface, the cup is filled in or has disappeared. The exposed cement core and the surrounding enamel ring are called the 'mark.'

Disappearance of the marks

The shape of the mark generally corresponds to the contour of the occlusal table of the incisor. In young horses marks are oval in the mesiodistal direction. When wear progresses, marks become smaller and rounder and move caudally (lingually) on the occlusal surface. With age, the cement of the infundibular bottom wears away and eventually the remaining enamel spot disappears from the occlusal surface.

Changes in shape of the incisors

Changes in shape of the occlusal surfaces (Fig. 7.5)

Due to extensive wear, the sequential shapes of the occlusal tables represent the cross-sections of the incisor teeth at various levels. The sequence ranges from oval in the mesio-distal direction, to trapezoid and triangular, and finally to oval in the labiolingual direction.

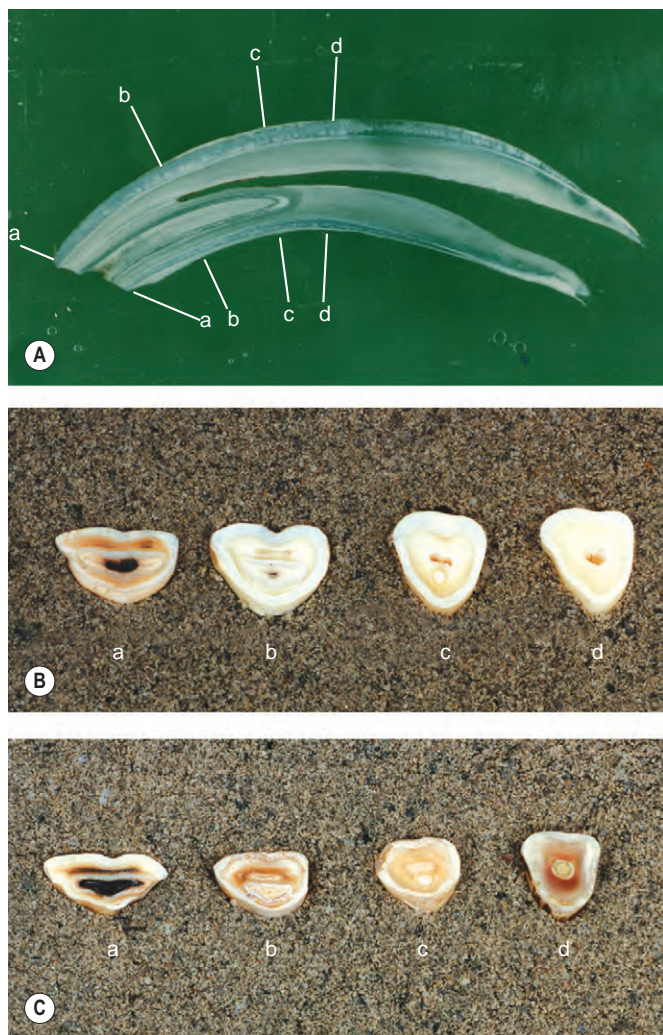


Fig. 7.5 (A) Longitudinal section of the lower central incisor of a Standardbred horse (4 years old). (B) Lower central incisor of a 5-year-old Standardbred horse. Cross-sections at various levels as indicated in (A). In the sections c and d, the pulpal cavity is open. (C) Occlusal tables of the lower central incisor of Standardbreds aged: a, 5 years; b, 8 years; c, 14 years; d, 20 years, respectively. In the occlusal tables c and d the pulpal cavity is occluded by secondary dentin.

Direction of upper and lower incisors (Fig. 7.6)

When incisors are viewed in profile, the angle between the upper and lower incisors changes with age. In young horses, the upper and lower incisors are positioned in a straight line (angle $\pm 180^\circ$) with each other. With age, the occlusal portions of the crowns wear off, and we look at different cross-sections of the crown shape in profile. The angle between upper and lower incisors becomes, therefore, increasingly acute. The lower incisors are the first to obtain an oblique position followed at a later date by the upper incisor teeth.

Length versus width of the upper corner incisor (Fig. 7.6)

The shape of the upper corner incisor has been used recently to categorize a horse's age into three groups from 5–20 years of age.⁸ Between 5 and 9 years of age the crown of this tooth

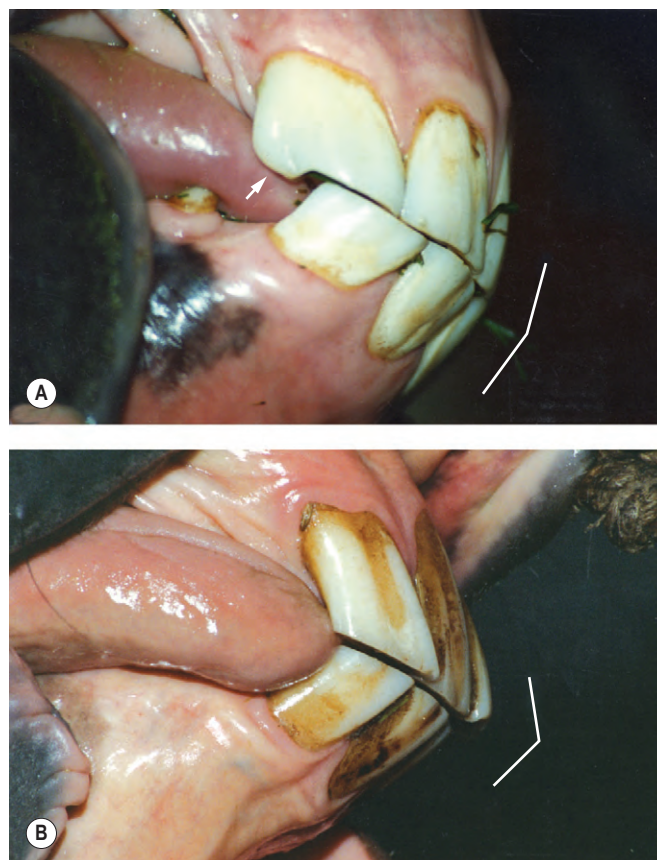


Fig. 7.6 (A) Belgian draft horse, 6 years old. The upper and lower incisors are positioned in a straight line with each other. The crown of the upper corner (103) is wider than it is tall. Notice the presence of a hook on the upper corner (arrow). (B) Standardbred horse, 16 years old. The angle between upper and lower incisors is more acute. The crown of the upper corner (103) is taller than it is wide. The upper corner presents a Galvayne's groove over the entire length of its labial surface.

is generally wider than it is tall. At ages 9–10, the upper corner appears square in most horses and then progresses to taller than it is wide as age increases.

The hook on the upper corner incisor (Fig. 7.6A)

The caudal edge of the upper corner sometimes exceeds the occlusal surface of the lower corner, especially when the lower incisors have acquired their oblique position. If the caudolateral portion of the upper corner is no longer in contact with its lower counterpart, it wears more slowly, forming a hook in the occlusal surface. Later, when the upper incisors obtain their oblique position and the caudal edge of the upper corner is in contact with its lower counterpart again, this notch can disappear.

The Galvayne's groove (Fig. 7.6B)

The Galvayne's groove is a shallow, longitudinal groove on the labial surface of the upper corner and is filled with dark stained cement. In the unworn tooth the groove starts halfway from occlusal surface to apex and continues

three-fourths of the distance to the apex. It is buried within the alveolus when the tooth first comes into wear.¹⁹ With age, and due to the prolonged eruption of the tooth, the Galvayne's groove first appears at the gumline. As the tooth continues to erupt, it extends down the labial surface to reach the occlusal edge, then starts to disappear at the gumline and finally disappears completely. The appearance of the groove and its usefulness in aging horses were mentioned for the first time in the early 1880s by an American horsetamer called Sample. Later, his theory was adopted by Sidney Galvayne, an Australian horseman.²⁰ It was in his first work, *Horse dentition: showing how to tell exactly the age of a horse up to thirty years* (published prior to March 1886) that Galvayne described the groove, which now bears his name, on the vestibular surface of the permanent upper corner incisor.²¹ The presence and length of the Galvayne's groove as an accurate guide to the age of the older horse became known throughout the English-speaking world. However, it was not until World War I that several investigations were undertaken to validate his theory.²⁰ Contrary to Galvayne's statements, these investigations showed that the groove may be absent in more than 50 % of the horses between the ages of 10 and 30 years.

Dental star morphology

The appearance of the dental star is, next to eruption times, one of the more reliable dental features, and the correlation between dental star morphology and age is stronger than for any other feature.²²

Horses at pasture have obvious darkly colored dental stars, whereas individuals without access to pasture or grass fodder usually have pale yellowish dental stars (Fig. 7.7). This suggests that the coloration of the dental star is caused by an impregnation of grass pigments. Two small experiments support this theory:²³

1. When equine incisors are sectioned longitudinally one can observe that the brown color of the dental star extends only a few millimeters beneath the occlusal surface and that the color intensity fades towards the pulpal chamber. This indicates that the color originates

from the 'outside world' rather than from the pulp as suggested in older literature reports.^{3,24}

2. When incisors with pale dental stars are stored in a mush of crushed grasses, dental stars become darkly colored after a few days; when they are stored in a buffered (pH 6.8) solution of various diphenols (caffeic acid, 3,4-dihydroxybenzoic acid and 3,4-dihydrophenylalanine (10 mmol/l) together with tyrosinase, the dental stars obtain a deep brown color after 72 hours (Fig. 7.8).

This suggests that food pigments are responsible for the dark color of the dental star.

Dental stars also present a topical coloration pattern. In young horses, the dental stars have a uniform color, whereas in older individuals they are composed of a darker periphery that surrounds an uncolored central zone, the so-called 'white spot' (Fig. 7.9). The reason why absorption of food pigments occurs only in the peripheral rim of the dental star and not in the white spot nor in the surrounding primary dentin can be found by examining the diameter, extent and orientation of the dentinal tubules.

Dentinal tubules are formed as the odontoblasts retreat centripetally and leave behind a cytoplasmatic process around which the dentin matrix is deposited and mineralized. The tubules can therefore be regarded as hollow cylinders traversing the dentin. Each tubule starts peripherally at the interface between the primary dentin and the enamel, and extends centripetally toward the pulpal border. The first dentin produced by the odontoblasts is located peripherally in the tooth, i.e., underneath the enamel, and is called primary dentin. It surrounds the younger and more centrally located secondary dentin, whereas tertiary dentin is only formed in the restricted areas between the tip of the pulp chamber and the occlusal surface.

The only obvious feature characterizing the transition between primary and secondary dentin of equine teeth is the presence of peritubular dentin (Fig. 7.10), which is hypercalcified tissue, deposited as a collar inside the tubular walls of primary dentin. The term peritubular dentin is



Fig. 7.7 Standardbred horse, 12 years old, deprived of fresh grass. Dental stars are yellowish (arrowheads). It is difficult to distinguish the white spot in the center of the stars.



Fig. 7.8 Lower central incisors of a 20-year-old Standardbred without access to pasture. The right tooth (401) was stored in a buffered Ringer's lactate solution; and the left one (301) was immersed in a buffered solution of 3,4-dihydroxybenzoic acid (10 mmol/l) for 48 hours. In 301, the periphery of the dental star has obtained a brown color (arrows).



Fig. 7.9 Occlusal surface of the left lower central incisor (301) of a 15-year-old draft horse. The dental star consists of a dark peripheral rim (asterisk) and a central white spot (arrow). The white spot is composed of secondary dentin (A) and a core of tertiary dentin (B).

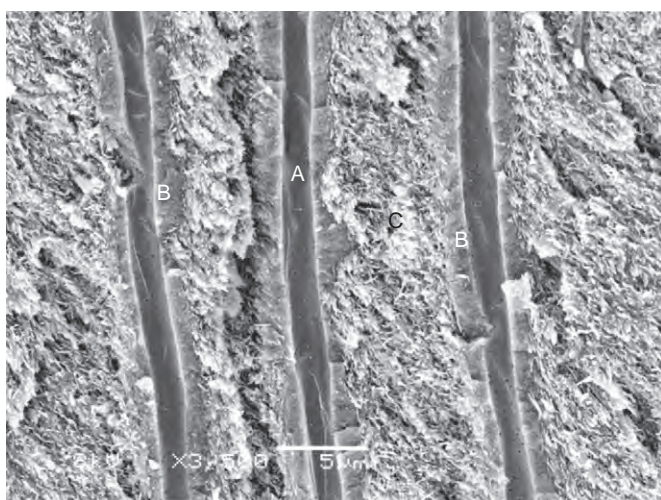


Fig. 7.10 SEM image of longitudinally fractured dentinal tubules. A, tubular lumen; B, peritubular dentin; C, intertubular dentin (x3500).

anatomically incorrect because this dentin forms within the dentinal tubule (not around it) and narrows the tubular lumen. It is, therefore, sometimes (more accurately) referred to as intratubular dentin.²⁵ Apart from the presence of peritubular dentin, the structure of dentinal tubules is identical in primary and secondary dentin. Peritubular dentin deposit is thickest at the outer end of the primary dentinal tubules and disappears at the transition between primary and secondary dentin.²³ The presence of peritubular dentin gives the tubules a tapered shape with the wider lumen at the pulpal side and the narrower luminal diameter near the enamel.

The dental star consists of a central core of tertiary dentin and a much broader ring of secondary dentin, in neither of which peritubular dentin is deposited. Tertiary dentin, situated in the very center of the dental star, is formed between the tip of the pulp chamber and the occlusal surface and protects the pulp from exposure to attrition. Penetration of

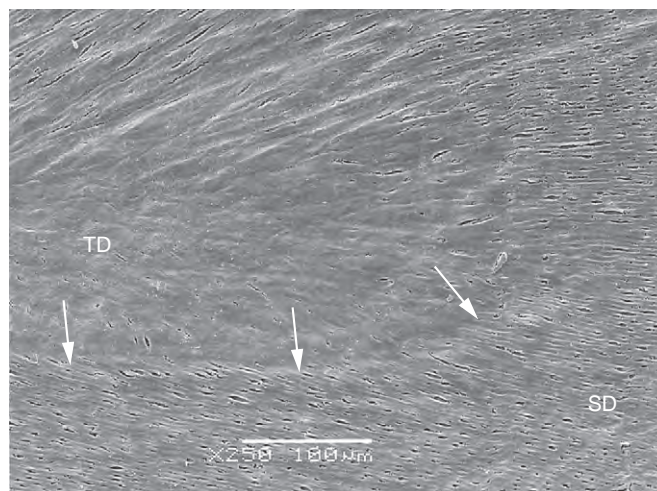


Fig. 7.11 SEM image of the occlusal surface at the center of the dental star. The boundaries of the tertiary dentin are indicated by arrows. TD, tertiary dentin; SD, secondary dentin (x250).

food pigments in this zone of the dental star is prevented by the small number of tubules, which are, for the most part, discontinuous with those of the surrounding secondary dentin, their irregular arrangement, and their small diameter (Fig. 7.11). This explains the colorless aspect of the central core of tertiary dentin inside the dental star.

The secondary dentin around the core of tertiary dentin consists of a pale inner zone and a brown peripheral zone. Both zones contain regularly arranged dentinal tubules that are continuous with those of the surrounding primary dentin and are completely devoid of peritubular dentin. The high numerical tubular density, the regular tubular arrangement, and the large tubular diameters of the secondary dentin are suggestive of an easy and uniform penetration of food pigments in this area. The only difference between the pale inner zone and the dark peripheral zone of secondary dentin is the spatial arrangement of the dentinal tubules. In the periphery of the dental star, tubules end perpendicularly into the occlusal surface (Fig. 7.12). This orientation allows an optimal inflow of food pigments, which is far superior to the dye penetration in the more central, uncolored secondary dentin, where tubules lie nearly parallel to the occlusal surface (Fig. 7.13). Penetration of food pigments in the latter zone is nearly negligible because due to the horizontal position of the tubules, the maximal penetration depth of food pigments in this zone cannot exceed the tubular diameter, which is 3 μm . Even when the horizontally exposed tubules are filled with food pigments, this 3 μm -thick mass of colored dentin is worn off in less than 1 day by the severe occlusal attrition, which amounts to 2500 μm a year. Food pigments can, therefore, not be accumulated in the inner zone of the secondary dentin of the dental star. This contrasts with the more peripheral zone of secondary dentin, where food pigments can permeate a longer distance in the perpendicularly debouching tubules. The pigments can accumulate within these tubules and thus cause the dark coloration of the dental star periphery. This mechanism is fully compatible with the aforementioned preliminary experiments, showing that secondary dentin acquires its dark color within 72 hours after immersion in a pigmented solution.²³

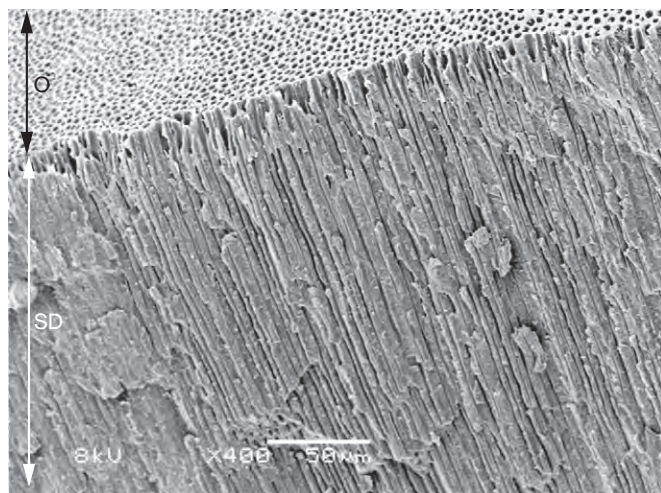


Fig. 7.12 SEM image of the etched occlusal surface (O) and the subjacent secondary dentin (SD) at the dark peripheral rim of the dental star of a longitudinally fractured incisor. Dentinal tubules end perpendicular to the occlusal surface (x400).

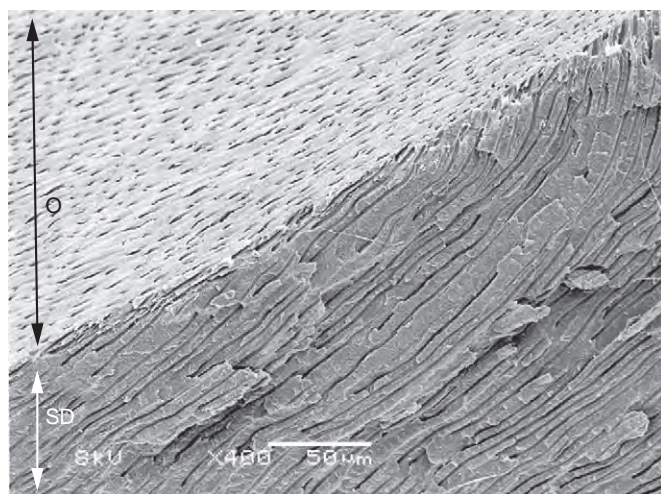


Fig. 7.13 SEM image of the etched occlusal surface (O) and the subjacent secondary dentin (SD) at the pale inner zone of secondary dentin in the dental star. The orientation of the tubules is almost parallel to the occlusal surface (x400).

The microstructure and spatial arrangement of the dentinal tubules can also explain the color differences between primary and secondary dentin. Primary dentin has a smaller number of tubules per area unit than secondary dentin and thus offers fewer pathways for food pigments to penetrate into the occlusal surface. In primary dentin, exposed onto the occlusal surface peripheral to the dental star, tubules debouch obliquely. For the reasons described above, penetration of food pigments into these tubular lumina is considerably less than in the dark peripheral rim of the dental star, where tubules end perpendicularly. Furthermore, primary dentin contains high levels of peritubular dentin and has an almost translucent appearance, which is similar to the complexion of enamel, as both tissue types are highly mineralized.²⁶ In contrast, the less mineralized secondary dentin has a dull opaque appearance. Additionally, because tubules in secondary dentin are devoid of peritubular dentin, they have

wider lumina in which plant pigments can penetrate more easily and give the dentinal tissue a dark brown color.

Dental aging in different horse breeds

Many standard textbooks dealing with aging of horses suggest that the above-mentioned characteristics give an accurate indication of a horse's true age. However, some reports are inconsistent in their guidelines and show large discrepancies in the dental features described at specific ages. A possible explanation for the non-uniformity of existing guidelines is the lack of evidence that any system was used to validate an author's recommendations for aging.^{27,28} A study performed by Richardson et al²⁹ casts serious doubts on the belief that the age of a horse can be determined accurately from an examination of its teeth. In this study a large group of horses with documented evidence of birth were examined, and age was estimated both by experienced clinicians and by a computer model. There was little difference between the accuracy of the computer model and the clinical observers, but neither method was accurate when compared with the actual age. In older horses, there was much greater variability between the dental age and the actual age, which means that the accuracy of dental aging declines markedly with age. Most standard texts do not provide exact data concerning breed, sex, and nutrition of the examined horses. However, anatomical, physiological, environmental, and behavioral differences between individuals ensure differences in rate of equine dental wear.³⁰ The concealment of these data may explain the discrepancies between different reports. Inaccuracies in the dental aging system of horses may also result from differences between breed and type of horse involved. Eisenmenger and Zetner stated that the teeth of Thoroughbreds erupt earlier than those of Lipizzaners and coldblood horses. Teeth of ponies may also have rates of eruption and wear that differ from the teeth of horses.³ As for donkeys, both ancient literature data³¹ and recent investigations³² have suggested that the degree of dental attrition in donkeys is slower than in horses.

The nature of diet can also play a part in the abrasion of horse incisors. Dental wear is caused not only by grinding of opposing crowns against one another, but also by contact with abrasive particles in food, such as silicate phytoliths which form part of the skeleton of grasses. Other plant-borne abrasives include cellulose and lignin.³⁰ In order to preclude the influence of the quality of nutrition on the rate of dental wear, it is necessary that horses that are examined for breed variability are raised and kept under similar environmental and nutritional conditions.

Based on the suggestions that the degree of attritional dental wear is correlated with the breed of horse, four unrelated horse breeds have been subjected to a comparative study.^{33–35} All horses examined here were raised in Western Europe, were given access to daily pasture, and were fed concentrates and hay. None of the horses was a crib-biter nor suffered from other vices with a possible influence on dental wear. The incisor teeth had not been rasped in any individual. It is evident that in practice one has to be vigilant for these considerations. Factors that are difficult to control and that could not be taken into consideration are the individual chewing habits and the amount of food intake.

A critical evaluation of the dental aging technique revealed that the rate of attritional dental wear is different in different horse breeds. Indentation hardness tests, performed with a Knoop diamond indenter, showed slight breed differences in the hardness of equine enamel and dentin. These different microhardness values seem to contribute to the differences in the rate of attritional dental wear.³⁶

The following text describes the appearance of lower incisor teeth at various ages as generally seen in the Standardbred horse, the Belgian draft horse, the Arabian horse, and the mini-Shetland pony population of Western Europe. It must be emphasized that this text is not a truism. When determining a horse's age, one must register all dental features together and take account of clinical factors that may have influenced the aspect of the horse's teeth. The following descriptions will therefore be accurate in many cases, but may be incorrect for any individual.

Eruption of the deciduous incisors

The central incisors generally erupt during the first week of life. The middle incisors emerge through the gums at 4–6 weeks, and the corners erupt between the sixth and the ninth month of life. In the mini-Shetland pony, eruption of the middle and the corner incisors is retarded. The middle incisor starts erupting at the age of 4 months, whereas the corner incisor breaks through the gums between 12 and 18 months of age.

Eruption of the permanent incisors

The upper and lower permanent incisors erupt almost simultaneously. In some horses shedding begins with the maxillary, in others with the mandibular incisor teeth. Arabian horses shed their central, middle, and corner incisors at 2.5, 3.5 and 4.5 years of age, respectively. In Standardbreds and in Belgian draft horses, shedding generally occurs later, namely at nearly 3, nearly 4, and nearly 5 years of age (Fig. 7.14). In mini-Shetland ponies, eruption of the permanent incisors is still further delayed by 2 or 3 months. In male horses, the canines erupt at about 4.5–5 years of age. Generally, these teeth are absent or rudimentary in mares.

Appearance of the dental star

Dental stars appear sequentially in the central, the middle and the corner incisors. In Standardbreds and in Arabian horses they appear on the centrals at 5 years, on the middles at 6 years, and on the corners at 7–8 years. In Belgian draft horses and mini-Shetland ponies, stars appear somewhat earlier, namely on the centrals at 4.5 years, on the middles at 5.5 years and on the corners at 6.5–7 years (Fig. 7.14). With age, the characteristic white spot becomes visible in the center of the dental star (Figs 7.15–7.17). In Standardbreds and in Arabian horses this white spot appears on the central incisors from the age of 7–8 years onwards, and on the middle incisors from the age of 9–11 years onwards. In Belgian draft horses and in mini-Shetland ponies the white spot becomes visible on the centrals at the age of 6–7 years and on the middles at the age of 8. In all breeds, the appearance of the white spot in the dental star of the corner incisors is variable and occurs between 9 and 15 years.

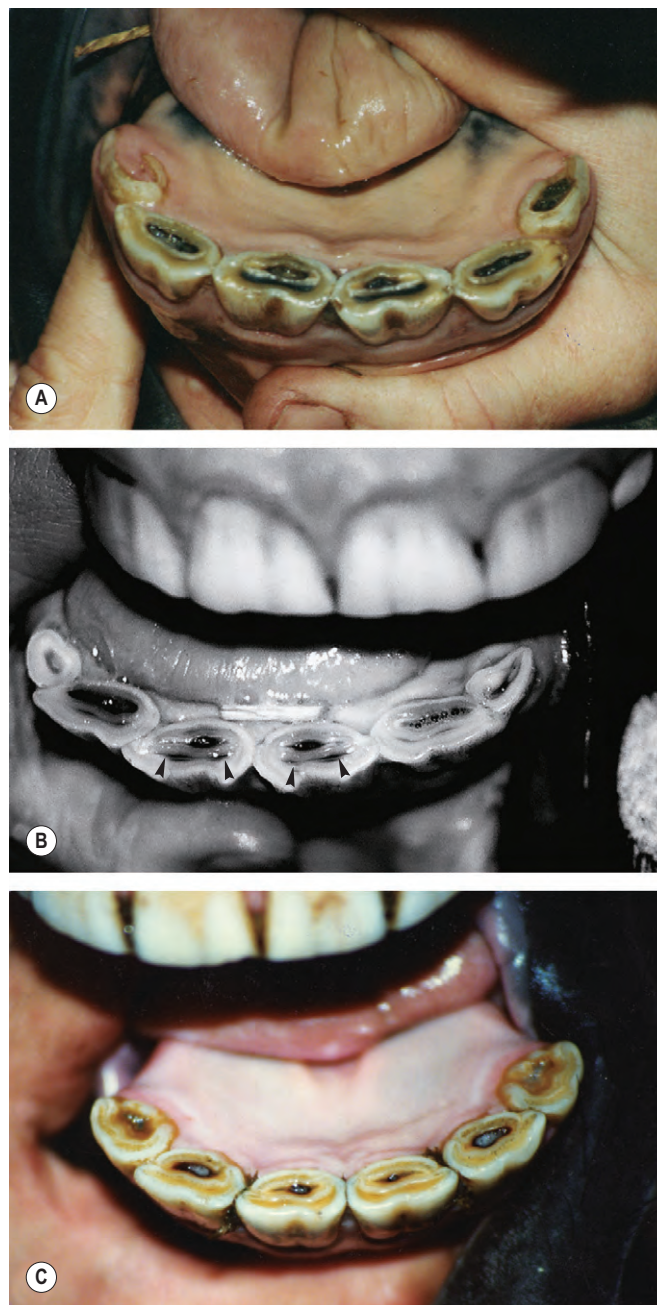


Fig. 7.14 (A) Standardbred horse, 5 years old. The permanent central and middle incisors are in place, the corner incisor is emerging through the gums. The dental star is present on the centrals, absent on the middles and the corners. All lower incisors have deep cups. (B) Belgian draft horse, 4 years and 8 months. The permanent central and middle incisors are in place. The corner incisors are still deciduous. Dental stars are present on the centrals (arrowheads) and appear also on the middles. Cups are present in the central and the middle incisors. (C) Arabian horse, 5 years old. All lower incisors are permanent, the corners are not yet fully in wear. There are no obvious dental stars. Deep cups are present on all lower incisors.

Disappearance of the cups

The disappearance of the cups is an unreliable feature for age determination because it does not occur between narrow age limits. In all breeds, cups on the central incisors disappear at the age of 6–7 years, whereas cups on the middle incisors are filled in variably between 7 and 11 years and



Fig. 7.15 (A) Standardbred horse, 8 years old. Dental stars are present on all incisors. In the central incisor, the white spot in the dental star becomes apparent (arrows). Cups are filled-in on the centrals. On the middles and the corners, cups are still present. The occlusal tables of the central incisors are becoming trapezoid, those of the middles and the corners are still oval. (B) Belgian draft horse, 8 years and 6 months. Dental stars are present on all incisors. In the central and the middle incisors, the white spot in the dental star becomes apparent (arrows). Cups are filled-in on all lower incisors. The remaining marks are oval. The occlusal tables of the centrals and the middles are becoming trapezoid. (C) Arabian horse, 8 years and 6 months. Dental stars are present on the central and the middle incisors. The white spot in the dental star is appearing in the central incisor. Cups on the centrals and the middles have nearly disappeared; the remaining marks are oval (middles) to triangular (centrals). Deep cups are still present on the corner incisors. The occlusal tables of the centrals become trapezoid.

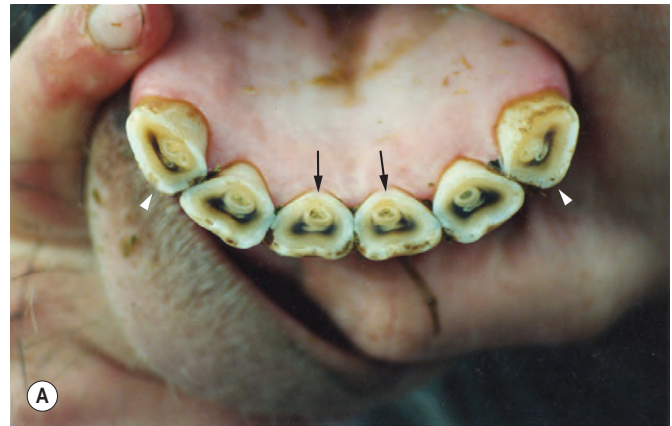


Fig. 7.16 (A) Standardbred horse, 12 years old. Dental stars, consisting of a white spot and a dark periphery, are present on all lower incisors. Cups have disappeared, and the marks are small oval to rounded. The occlusal tables of the central and the middle incisors are trapezoid. On the central incisor, the lingual apex is visible (arrows). The corner incisors have an apex on the labial side (arrowheads). (B) Belgian draft horse, 12 years old. Dental stars, consisting of a white spot and a dark periphery, are present on all lower incisors. Marks are rounded, and on the central incisors they have almost disappeared. The occlusal tables of the centrals and the middles are trapezoid. On the corner incisor, the labial apex is obvious (arrowheads). (C) Arabian horse, 12 years old. Dental stars are present on all lower incisors. On the central and the middle incisors, the white spot in the dental star is visible. Cups have disappeared. The remaining marks are oval and still clearly visible. The occlusal tables of the centrals and the middles are trapezoid. The corner incisor presents a labial apex.

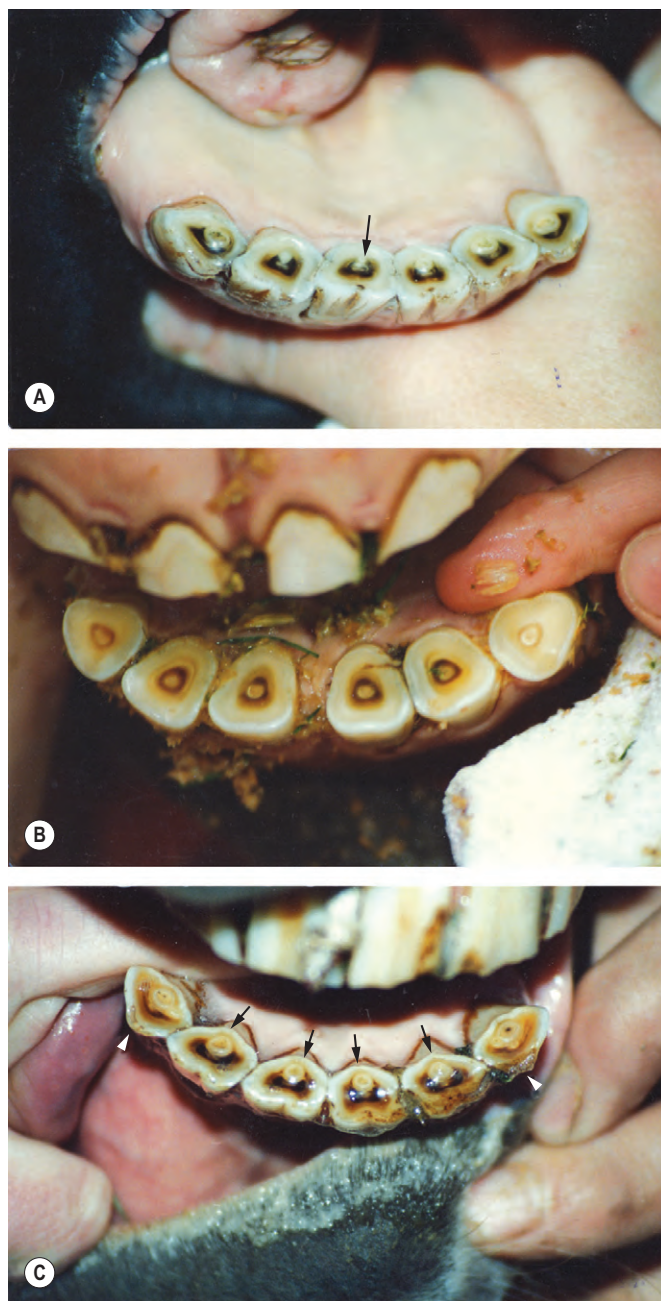


Fig. 7.17 (A) Standardbred horse, 18 years old. Marks are small and rounded. On the central incisors, they have almost disappeared (arrow). The occlusal tables of the centrals and the middles are trapezoid, those of the corner incisors are triangular with an apex to the labial side. (B) Belgian draft horse, 18 years old. Marks have disappeared from all lower incisors. The occlusal surfaces are triangular; those of the central and the middle incisors have a lingual apex, and those of the corners have a labial apex. (C) Arabian horse, 18 years old. Round marks are still clearly visible on all lower incisors. The occlusal surfaces of the centrals and the middles are trapezoid with a lingual apex (arrows); those of the corner incisors are oval with a labial apex (arrowheads).

those on the corners between 9 and 15 years. The variations in the age at which the cups disappear may be due to a difference in the depth of the cup. The accumulation of cement in the infundibulum is variable, i.e., superabundant in some individuals and almost non-existent in others.

Changes in shape of the marks

On the central incisors, big oval marks are visible until the age of 6–7 years. These marks become oval to triangular from the age of 7–8 years onwards in Belgian draft horses, from the age of 8–10 years onwards in Standardbreds and Arabian horses, and from the age of 10 years onwards in mini-Shetlands. Round marks on the central incisors are visible at 9–10 years in Belgian draft horses, at 13–14 years in Standardbreds and mini-Shetlands, and at 15–17 years in Arabian horses (Fig. 7.17).

Disappearance of the marks (Fig. 7.17)

From all age-related dental characteristics, the disappearance of the marks is the one with the highest interbreed variability. In draft horses, marks on the central incisors disappear from the age of 12–15 years, and those on the middles and the corners from the age 14–15 years onwards. In mini-Shetland ponies, marks on the central, the middle, and the corner incisors disappear at the age of 15, 16, and 17 years, respectively. In Standardbred horses, marks disappear some years later. On the centrals, they vanish in 18-year-old horses while disappearing on the middle and the corner incisors in 19- to 20-year-olds. In Arabian horses, marks on the lower incisors may persist for a very long time. They start disappearing at the age of 20 but exhibit considerable individual variations.

Changes in shape of the occlusal surfaces

Changes in shape of the occlusal surfaces of the lower incisors are useful but inaccurate indicators of age. The changes are difficult to judge objectively because successive shapes shade off into one another and are not easily distinguishable. The sequential shapes of the tables of the central and the middle incisors are oval, trapezoid, triangular with the apex pointing to the lingual side, and biangular. A survey of the most important changes is given in Tables 7.1–7.4. It is striking that the shape of the lower corner incisor does not conform to the sequential changes described above. The lower corners remain oval for a long time and gradually develop an apex at the labial side. In Belgian draft horses and mini-Shetland ponies, a labial apex appears at the age of 9, and in Standardbreds at the age of 11. In Arabian horses, the apex is a constant characteristic in individuals aged over 12 years (Figs 7.16 & 7.17).

Direction of upper and lower incisors

The arch formed by the incisors of the opposing jaws as they meet, when viewed in profile, changes as the teeth advance from their alveoli and undergo attrition (Fig. 7.6). In young horses, the upper and lower incisors are positioned in a straight line ($\pm 180^\circ$). From the age of approximately 10 years onwards, the angle between upper and lower incisors becomes more acute. Because exact measurements of the age-related incisive angle are not available, the evaluation of the angle provides only a rough estimate of an animal's age. The same applies for the curvature of the dental arch formed by the lower incisive tables. In young horses this arch is a semicircle, whereas in older individuals it forms a straight

Table 7.1 Aging Belgian draft horses

	I1	I2	I3
Shedding	±3 y	±4 y	±5 y
Appearance of the dental star	4.5 y	5.5 y	6.5 y–7 y
Appearance of the white spot in the dental star	6–7 y	7–8 y	11–13 y
Disappearance of the cup	5–8 y	7–11 y	9–15 y
Shape of the mark: oval oval-triangular round	until 6 y ≥7 y–8 y ≥9 y–10 y		
Disappearance of the mark	12–15 y	14–15 y	14–15 y
Shape of the occlusal table: oval trapezoid trapezoid with lingual apex labial apex on 303 or 403	until 6 y ≥7 y ≥7 y	until 7 y ≥8–9 y ≥9 y	until 10 y – – ≥9–10 y
Hook on 103 or 203			≥5 y
Galvayne's groove			≥11 y

Table 7.3 Aging Arabian horses

I.	I1	I2	I3
Shedding	±2.5 y	±3.5 y	±4.5 y
Appearance of the dental star	5 y	6 y	7 y–8 y
Appearance of the white spot in the dental star	7–8 y	9–11 y	13–15 y
Disappearance of the cup	7 y	7–11 y	9–15 y
Shape of the mark: oval oval-triangular round	until 7 y ≥8–10 y ≥15–17 y		
Disappearance of the mark	≥20 y	≥20 y	≥20 y
Shape of the occlusal table: oval trapezoid trapezoid with lingual apex labial apex on 303 or 403	until 6 y ≥8–9 y ≥10–11 y	until 7 y ≥9–11 y ≥14 y	until 12 y – – ≥12 y
Hook on 103 or 203			≥5 y
Galvayne's groove			≥11 y

Table 7.2 Aging Standardbred horses

	I1	I2	I3
Shedding	±3 y	±4 y	±5 y
Appearance of the dental star	5 y	6 y	7 y–8 y
Appearance of the white spot in the dental star	7–8 y	9–11 y	11–13 y
Disappearance of the cup	6–7 y	7–11 y	9–15 y
Shape of the mark: oval oval-triangular round	until 6 y 8 y–10 y ≥13 y		
Disappearance of the mark	18 y	19–20 y	19–20 y
Shape of the occlusal table: oval trapezoid trapezoid with lingual apex labial apex on 303 or 403	until 6 y ≥7 y ≥9 y	until 7 y ≥8 y–9 y ≥10 y	until 12 y – – ≥10–11 y
Hook on 103 or 203			≥5 y
Galvayne's groove			≥11 y

Table 7.4 Aging mini-Shetland ponies

	I1	I2	I3
Shedding	≥3 y	±4 y	±5 y
Appearance of the dental star	4.5 y	5.5 y	6.5–7 y
Appearance of the white spot in the dental star	6–7 y	8 y	10–12 y
Disappearance of the cup	7–8 y	8–12 y	9 y–13 y
Shape of the mark: oval oval-triangular round	until 8 y ≥10 y ≥13 y		
Disappearance of the mark	15 y	16 y	17 y
Shape of the occlusal table: oval trapezoid trapezoid with lingual apex labial apex on 303 or 403	until 6 y ≥7 y ≥11–12 y	until 7 y ≥8–9 y ≥14 y	until 10 y – – ≥9–10 y
Hook on 103 or 203			≥5 y
Galvayne's groove			≥11 y

line. In view of the gradual character of this change in direction, however, it is impossible to determine the exact age at which it occurs.

The hook on the upper corner

The hook on the caudal edge of the upper corner incisor has long been considered as the typical characteristic for a 7- or 13-year-old horse. However, hooks on 103 and 203 are seen in a minority of horses and occur at practically any age over 5 years. Only 13 % of all 7-year-olds and 8 % of all 13-year-olds that were examined for this study presented a hook on one or both upper corners. On the other hand, hooks were also seen in 14 % of the 5- and 6-year-old horses, in 22 % of the horses aged between 8 and 12, and in 13 % of all horses aged over 13 years. As the presence of hooks on 103 and 203 cannot be related to any specific age category, it is considered irrelevant for the estimation of age in horses.

The Galvayne's groove

The Galvayne's groove is a feature that is most often observed in horses aged over 11 years. However, as its presence, length and bilateral symmetry are variable and inconsistent, the groove is considered to be of little value for age determination in horses.

Conclusion

Teeth provide a practical available tool for estimating age in horses. Aging an individual horse from its dentition,

however, is a complex process and all above-mentioned features should be carefully examined. It must be emphasized that dental aging in horses can only provide an approximate guess rather than an exact evaluation. In older horses, most of the so-called characteristic features can only be judged subjectively. It is obvious that the accuracy of the dental age determination declines markedly with age.

An important factor that can interfere with an accurate dental age determination in horses is the breed-dependence of the attritional dental wear. A comparison of the dental criteria in different breeds revealed that, in general, the incisor teeth of draft horses and mini-Shetland ponies are more liable to attrition, whereas the incisors of Arabian horses wear more slowly than those of Standardbred horses.

A variety of other factors such as nature and quality of food, environmental conditions, heredity, injury, and disease can also influence dental wear. It is, therefore, important that equine clinicians do not claim levels of accuracy that are unjustifiable. As it is impossible to assign specific ages to each dental feature, accuracy of age estimation in certain individuals can be very low.

Therefore, it is advisable to make written records at the time of examination to show the dental features upon which the age estimate was made. In some countries, there have been legal guidelines established to distance veterinarians from trying to state the age of a horse solely from dental findings. In case of insurance policies or legal questions, the veterinarian should indicate explicitly that he is providing an 'estimate of age.' It is also advisable that the incisor tables are photographed. When necessary, the pictures can be submitted to others for a second opinion and can be stored with appropriate identification for further use as well.⁸

References

1. Ten Cate AR. Physiologic tooth movement, eruption and shedding. In: Ten Cate AR, ed. Oral histology, development, structure and function, 5th edn. CV Mosby, St Louis, 1998, pp 289–314
2. Muylle S, Simoens P, Lauwers H. Age-related morphometry of equine incisors. *Journal of Veterinary Medicine A* 1999; 46: 633–643
3. Eisenmenger E, Zetner K, eds. Veterinary dentistry. Lea & Febiger, Philadelphia, 1985, pp 2–26
4. Kertesz P. In search of Mr Bishop. *Veterinary Record* 1993; 133: 608
5. Zipperlen W. Over de ouderdomskennis van het paard of de tandleer. In: Geïllustreerd veeartsenijkundig handboek. B. Dekema, Utrecht, 1871, p. 171
6. Dupont M. L'âge du cheval. Librairie J B Baillière, Paris, 1901
7. Frateur JL. De Ouderdomsbepaling van het Paard door het Gebit. E Marette, Brussel, 1922
8. American Association of Equine Practitioners. Official Guide for Determining the Age of the Horse, 6th edn. Fort Dodge, Iowa, 2002
9. Barone R. Dents. In: Anatomie comparée des mammifères domestiques. Tome 3, 3rd edn. Vigot, Paris, 1997, p 91
10. Dyce KM, Wensing CJ. Anatomie van het paard. Scheltema-Holkema, Utrecht, 1980, p 14
11. Willems A. Ouderdomsbepaling van het Paard, 5th edn. Van de Sompele, Oud-Heverlee, 1980, p 14
12. Habermehl KH. Wie sicher ist die Altersbestimmung beim Pferd? *Berliner und Münchener Tierärztliche Wochenschrift* 1981; 94: 167
13. McMullan WC. Dental criteria for estimating age in the horse. *Equine Practice* 1983; 5: 10, 36
14. Walmsley JP. Some observations on the value of ageing 5–7-year-old horses by examination of their incisor teeth. *Equine Veterinary Education* 1993; 5: 295
15. Sack WO. Rooney's Guide to the dissection of the horse, 6th edn. Veterinary Textbooks, Ithaca, 1994, p 182
16. Navin JN. The age. In: Navin's Veterinary practice. John B. Hann, Indianapolis, 1882, pp 431–446
17. Carmalt JL, Allen AL. Morphology of the occlusal surfaces of premolar and molar teeth as an indicator of age in the horse. *J Vet Dent* 2008; 25(3): 182–188
18. Dyce KM, Sack WO, Wensing CJ. Textbook of veterinary anatomy, 2nd edn. W B Saunders, Philadelphia, 1996, p 491
19. St Clair LE. Teeth. In: Sisson and Grossman's The anatomy of the domestic animals, 5th edn. W B Saunders, Philadelphia, 1975, p. 460
20. McCarthy PH. Galvayne: the mystery surrounding the man and the eponym. *Anatomia Histologia Embryologia* 1987; 16: 330
21. Galvayne S. Horse dentition: showing how to tell exactly the age of a horse up to thirty years. Thomas Murray, Glasgow, 1886
22. CD Equus – Vetstream Ltd, Three Hills Farm, Bartlow, Cambridge CB1 6EN, UK
23. Muylle S, Simoens P, Lauwers H. A study of the ultrastructure and staining characteristics of the dental star of equine incisors. *Equine Veterinary Journal* 2002; 34: 230–234
24. Joest E, Becker E. Zähne. In: Handbuch der speziellen pathologischen Anatomie der Haustiere, 3rd edn. Verlag Paul Parey, Berlin, 1970, pp 83–315

25. Torneck CD. Dentin-pulp complex. In: Ten Cate AR, ed. Oral histology, development, structure and function, 5th edn. CV Mosby, St Louis, 1998, pp 150–196
26. Kilic S, Dixon PM, Kempson SA. A light microscopic and ultrastructural examination of calcified dental tissues of horses: III Dentine. *Equine Veterinary Journal* 1997; 29: 206–212
27. Richardson JD, Cripps PJ, Hillyer MH, et al. An evaluation of the accuracy of ageing horses by their dentition: a matter of experience? *Veterinary Record* 1995; 137: 88
28. Richardson JD, Lane JG, Waldron KR. Is dentition an accurate indication of the age of a horse? *Veterinary Record* 1994; 135: 31
29. Richardson JD, Cripps PJ, Lane JG. An evaluation of the accuracy of ageing horses by their dentition: can a computer model be accurate? *Veterinary Record* 1995; 137: 139
30. Hillson S. *Teeth*. Cambridge University Press, Cambridge, 1986, p. 183
31. Marcq J, Lahaye J. *Extérieur du cheval*. J Duculot, Gembloux, 1943, p. 11
32. Misk NA. Radiographic studies on the development of incisors and canine teeth in donkeys. *Equine Practice* 1997; 19: 23
33. Muylle S, Simoens P, Lauwers H. Ageing horses by an examination of their incisor teeth: an (im)possible task? *Veterinary Record* 1996; 138: 295–301
34. Muylle S, Simoens P, Lauwers H, van Loon G. Ageing draft and trotter horses by their dentition. *Veterinary Record* 1997; 141: 17–20
35. Muylle S, Simoens P, Lauwers H, van Loon G. Ageing Arab horses by their dentition. *Veterinary Record* 1998; 142: 659
36. Muylle S, Simoens P, Verbeeck R, et al. Dental wear related to the microhardness of enamel and dentine. *Veterinary Record* 1998; 144: 558–561

Disorders of development and eruption of the teeth and developmental craniofacial abnormalities

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Craniofacial abnormalities

Foals can develop a variety of growth abnormalities of their craniofacial bones that cause malocclusion of their teeth and possible permanent changes to their dental function. Although some of these abnormalities, such as overbite ('parrot mouth'), are often regarded as being primary dental abnormalities, it must be remembered that the observed dental abnormality is just a manifestation of a significant skeletal abnormality and correction of the dental abnormalities, such as reduction of dental overgrowths, will not correct the underlying craniofacial abnormality.

Overjet and overbite

Many horses have some degree of **overjet** ('overshot jaw'), i.e., where the occlusal aspects of the upper incisors project rostral to the occlusal aspects of the lower incisors (Fig. 8.1). Untreated cases of severe overjet generally develop **overbite**, where the upper incisors lie rostral to the lower incisors as above but additionally now lie directly in front of the lower incisors ('parrot mouth'; Fig. 8.2). These disorders are commonly termed brachygnathism (indicating shortness of mandible), but in horses they may actually be due to overgrowth of the upper jaw.¹ With overbite, the upper incisors may mechanically trap the lower incisors behind them and so restrict mandibular growth; this in turn further exaggerates the disparity in length between the upper and lower jaws. Overjet, and more so overbite, are esthetically undesirable, especially in show horses, but unless contact between opposing incisors is totally absent, these problems rarely cause difficulty in prehension.² As the more rostral incisors (01s, central incisors) have the least occlusal contact, they overgrow most and so affected horses develop a convex appearance of their upper incisor occlusal surface (termed a 'smile'), which should be reduced if pronounced.^{2,3} This reduction should be performed in stages in order to prevent pulpar exposure. In contrast to having their CT floated, many

horses greatly resent incisor teeth floating and require sedation for this procedure.

The main clinical significance of incisor overjet or overbite is that affected horses usually have concurrent CT disorders, due to the upper CT row being rostrally positioned in relation to its lower counterpart.³ This leads to focal overgrowths on the rostral aspects of the upper 06s and the caudal aspects of the lower 11s, as discussed below. The treatment of overjet and overbite are discussed in Chapter 19, and of CT overgrowths in Chapter 17.

Underjet

Underjet (prognathism, 'sow mouth,' 'undershot jaw'; Fig. 8.3) is rare in horses and is usually of little clinical significance unless there is total lack of occlusion between incisors. In contrast to horses with overjet, those with underjet usually develop focal CT overgrowths on the caudal aspects of the upper 11s and the rostral aspects of the lower 06s. Due to preferential overgrowth of the lower 01s, such cases develop a concave occlusal surface of their upper incisor occlusal surface (termed a 'frown'). Similar to overbite, major incisor overgrowths and concurrent CT focal overgrowths are the main consequences of underjet, and such overgrowths should be reduced at 6-month intervals.

Rostral positioning of the upper CT rows

Rostral positioning of the upper CT rows relative to their mandibular counterparts is caused by an imbalance in craniofacial bone growth and as noted earlier, is usually associated with incisor overjet/overbite. This abnormality can rarely occur independent of incisor malocclusions. Because the upper and lower CT rows are not in full contact in this disorder, localized dental overgrowths (colloquially termed 'beaks', 'hooks', and 'ramps') develop on the rostral aspect of the upper 06s, and these overgrowths may be pressed against the lips and cheeks by the bit and so cause



Fig. 8.1 Mild overjet in a 3-month-old Thoroughbred foal.



Fig. 8.2 This foal has both marked overjet and overbite, with ventral deviation of the premaxilla (incisive bone).



Fig. 8.3 This adult donkey has underbite, i.e. the lower incisors lie directly in front of the upper incisors. (Image courtesy of Dr Nicole du Toit.)

mucosal ulceration and biting problems. If large, these overgrowths can also restrict the normal, but variable, rostrocaudal mandibular movement, relative to the maxilla, while lowering and raising the head.⁴ Feeding affected horses fully from the ground rather than from a height may also promote normal rostrocaudal mandibular movement and so help reduce the development of such overgrowths. Smaller 06 overgrowths can be fully reduced manually, but if large, then motorized dental instruments are required, and such overgrowths should be removed in stages, as described in Chapter 17.

Similar overgrowths may also develop on the caudal aspect of the lower 11s, but due to the later eruption of the 11s in comparison to the 06s, mandibular 11 overgrowths may not develop until affected horses are 5–6 years of age. These lower 11 overgrowths may remain undetected unless a full dental examination is performed.^{2,3} True lower 11 caudal overgrowths must be differentiated (e.g., by visually or digitally assessing crown height above gingival margin) from an anatomically normal, upward sloping caudal CT occlusal surface ('curve of Spee'), which can be especially marked in some smaller equine breeds (e.g., Arabian and Welsh ponies). Lower 11 overgrowths can traumatize the adjacent oral mucosa during mastication, and if large enough, can even lacerate the hard palate and the greater palatine artery or cause an oromaxillary fistula. Because there is very little room between the caudal aspect of the lower 11s and the vertical ramus of the mandible and the soft tissue protrusion caudal to the lower 11s, the mandible and adjacent soft tissue can be readily traumatized when manually reducing (floating, rasping) overgrown lower 11s. Consequently, sedation is usually necessary to both fully evaluate and if necessary, carefully and in stages, reduce larger lower 11 overgrowths.

If lower 11s are very overgrown, they are best reduced in stages from their medial aspects using motorized dental instruments^{2,5,6} as described in Chapter 17, whilst maintaining the normal high occlusal angulation of caudal mandibular CT.⁷ The use of 'molar cutters', cold chisels, or percussion guillotines (that encircle these caudal 11 overgrowths), risks fracturing the tooth and causing pulpar exposure, which can lead to cellulitis of the mandibular, oral, and pharyngeal areas.

Wry nose (campylorrhinis lateralis)

Wry nose is a syndrome involving shortening and/or deviation of the premaxillary (incisive) and maxillary bones that can also involve the nasal and vomer bones.⁸ In addition to possible disturbances to nasal airflow, malocclusions of the incisors (Fig. 8.4) and of teeth on the extremities of one of the CT rows can occur. Milder cases later develop a diagonal incisor occlusal plane ('diagonal bite', 'slope mouth', 'slant mouth') and unilateral upper 06, and lower 11 CT overgrowths. All cases of diagonal occlusal bite should be assessed for the presence of wry nose, which may be subtle in some cases. Affected foals can have a variety of surgical and orthodontic treatments for this disorder with limited success.⁸ Affected horses should have 6-monthly floating of excessively sloped incisors and also of any CT overgrowths, bearing in mind that they cannot be permanently corrected.



Fig. 8.4 This 8-week old foal has severe wry nose, with complete absence of contact of some incisors.

Disorders of dental development

Hypodontia (anodontia)

Hypodontia refers to reduced numbers of teeth, whilst anodontia technically refers to total absence of teeth; however, the terms are sometimes interchangeably used. Hypodontia is an abnormality of differentiation of the dental lamina and tooth germs (as are the presence of supernumerary teeth).⁹ Developmental hypodontia is relatively uncommon in horses, with absence of equine teeth usually caused by loss due to trauma, disease or to wear. Hypodontia generally affects the permanent equine dentition (Figs 8.5 & 8.6). This disorder is hereditary in humans and can be part of many generalized developmental syndromes.⁹ In many species (including the horse), multiple hypodontia is often associated with the presence of other dental abnormalities (such as dysplastic teeth) or even generalized ectodermal disorders including the ectodermal dysplasia syndrome.¹⁰

Supernumerary teeth

The presence of supernumerary (additional) teeth, also termed **polydontia** or hyperdentition, is relatively uncommon in the horse, but the exact prevalence is unknown.^{11,12} Colyer found a prevalence of 0.6% supernumerary incisors and 2.4% supernumerary cheek teeth in 484 museum skulls, whilst Wafa found a 0.3% prevalence of incisors in an abattoir survey of 355 skulls.^{1,13} Canine teeth are uncommon in mares, but these teeth are not generally considered as supernumerary teeth, but as atavism, i.e., the reappearance of a characteristic of a distant ancestor that is not found in its immediate ancestors.¹ Dentigerous cysts are also not considered to be supernumerary teeth in this review.

Supernumerary teeth can be categorized on their appearance into three types, i.e., **supplemental teeth** which resemble teeth of normal series in crown and root morphology,

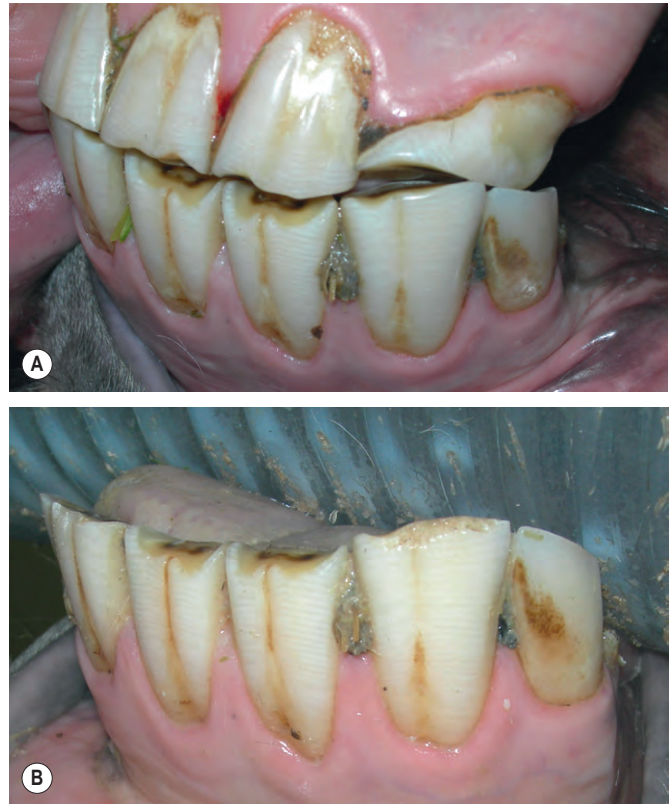


Fig. 8.5 (A) This young horse has developmental absence of 202, with mesial (medial) drifting of 203 into its site, with consequent overgrowth of the unopposed opposite 302, that is more obvious when the mouth is open (B). A diastema between 301 and 302 may be due to the overgrowth of 302 causing it to be laterally (distally) displaced.

though not always in size. Consequently, it is often impossible to differentiate supplemental from normal teeth.^{1,9,11}

Haplodont supernumerary teeth are characterized by their simple, usually conical crowns with single roots (Fig. 8.7). **Tuberculate supernumerary teeth** have complex crowns with several tubercles on the occlusal surface with deep indentations between the raised tubercles.^{1,9} A **connate tooth** is composed of two or more tooth elements, possibly arising from fusion of multiple tooth germs or alternatively from a partial splitting of an embryonic tooth.^{1,9} Connate teeth are not necessarily supernumerary teeth, but some supernumerary equine cheek teeth are connated, including 6 of the 10 supernumerary cheek teeth described by Dixon et al.¹² Connated supernumerary teeth have also been illustrated by Miles and Grigson, including a connated incisor with two fused crowns sharing separate roots.¹ The relationship between connated and tuberculate supernumerary teeth is unclear.

Supernumerary teeth are a developmental defect and may arise due to localized excessive odontogenic capacity, or from the splitting of a tooth primordium.^{1,9} With supplemental supernumerary teeth, it is believed that the primordium divides into equal parts, each with the capacity to form a tooth of normal morphology. Haplodont and tuberculate supernumerary teeth may be due to division of the primordium into parts which do not have the capacity to form a tooth of normal shape and size.⁹

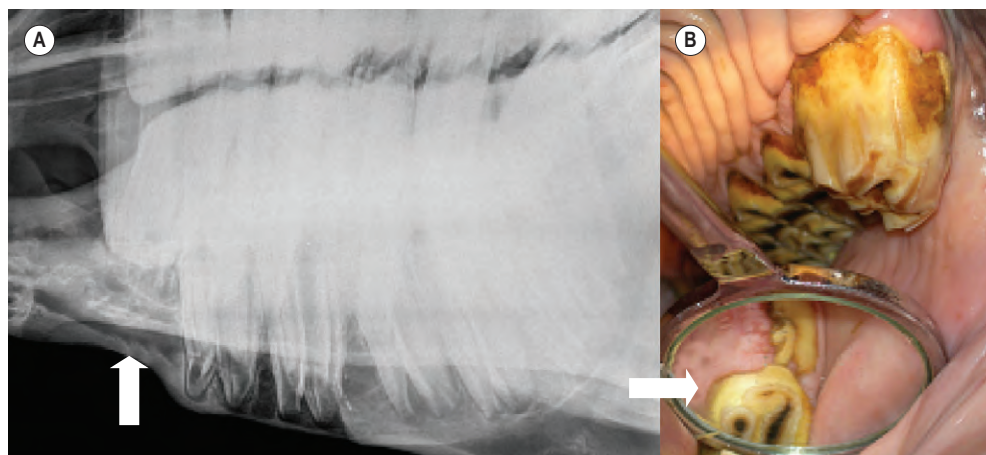


Fig. 8.6 (A) This skull radiograph shows absence of 306 (an intercurrent sclerotic, eruption cyst lies beneath the 307). (B) Intra-oral examination shows marked overgrowth of the opposing 206, with just a remnant of the deciduous tooth (706) visible in the intra-oral mirror. Such retention of deciduous teeth remnants is common in hypodontia, due to absence of pressure from an underlying erupting permanent CT to aid shedding.

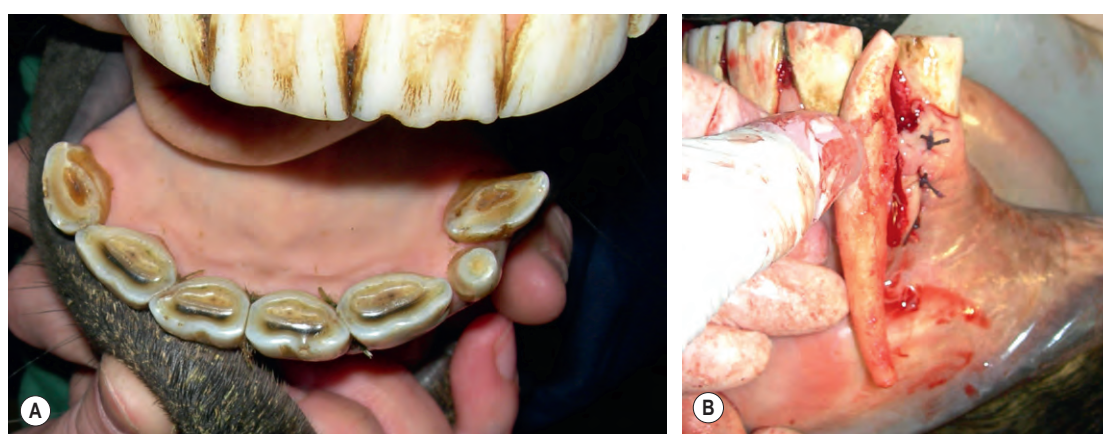


Fig. 8.7 (A) This horse has a haplodont supernumerary incisor lying between 302 and 303 that has caused caudal displacement of the 303. Despite having a relatively small clinical crown, radiographs confirmed the great length and outlined the shape of the reserve crown and apex of this supernumerary tooth. (B) The 9 cm long supernumerary tooth was extracted by removal of the rostral alveolar wall, and the gingival wound was partially sutured.

Equine supernumerary teeth often occur at the peripheries of the different classes of teeth, especially at the caudal aspect of the molar teeth,^{1,14,15} and in particular, caudal to the upper 11s,^{12,16} and this is also a relatively common site for supernumerary teeth development in other species, including humans, where a midline (pre)maxillary incisor is the most common supernumerary tooth.^{17,18} Supernumerary equine cheek teeth can also occur lingually, buccally, and rostrally to the normal cheek teeth row.^{12,15,16} Supernumerary teeth are generally more common in permanent than in deciduous teeth, in incisors than other classes of teeth, and are more common in maxillary than mandibular teeth.^{9,17,18} Supernumerary teeth are present in 0.8% of primary dentition and in 2.1% of permanent dentition in humans.¹⁸

Supernumerary incisors

In contrast to human supernumerary incisors, equine supernumerary incisors have been said to only occur in the permanent dentition,¹⁹ more commonly in the premaxillary incisors.¹¹ Supernumerary incisors are believed to occur more frequently in horses than supernumerary cheek teeth,^{14,15} as is the case in humans where circa 90% of all supernumerary teeth are reported to be premaxillary incisors;¹⁷ however,

Colyer (1906) recorded a 0.6% prevalence of equine supernumerary incisors whilst finding a 2.5% prevalence of supernumerary CT.¹ Equine supernumerary incisors are usually supplemental teeth, i.e., are morphologically similar to normal incisors.¹¹ Occasionally, a complete supplementary set of incisors (six) can occur,^{11,13,19} but more commonly, only one or two supernumerary incisors develop, and protrude rostrally to the normal premaxillary (incisive) incisors (Fig. 8.8).¹⁶

Because of their normal morphology, supplemental supernumerary incisors can readily be confused with retained deciduous incisors. This is particularly the case with larger retained incisors, whose permanent successors erupted beside, rather than beneath, the deciduous incisor, and thus have not caused any resorption or mechanical displacement of the apex or reserve crown. Radiography usually distinguishes between a retained deciduous and supernumerary incisor, as a retained deciduous incisor is shorter and narrower than a supernumerary permanent incisor (see later), in contrast to supernumerary incisors that are usually of similar size (Fig. 8.8). Supernumerary incisors may cause overcrowding and displacement of the normal permanent incisors, and diastemata often occur beside the displaced incisors. A rostrally displaced supernumerary

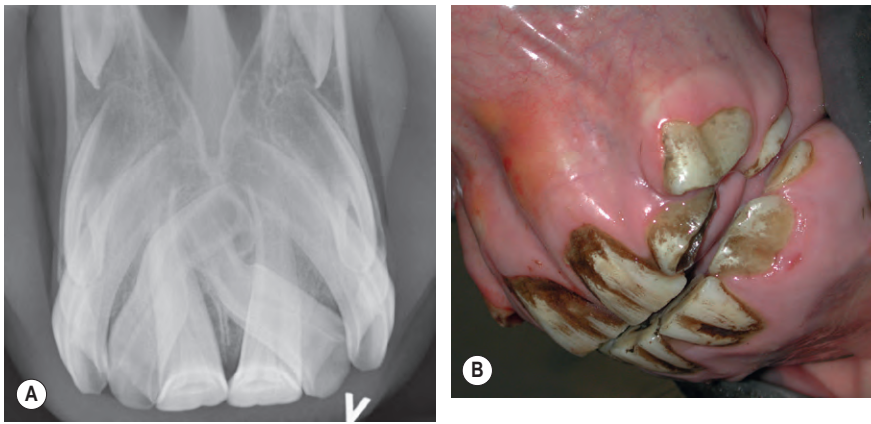


Fig. 8.8 (A) Intra-oral radiograph of a premaxilla containing two bent, supplemental supernumerary (permanent) incisors lying at oblique angles, that have caused overcrowding and displacement of the remaining incisors. (B) One of these supernumerary incisors is visible, abnormally protruding at an oblique angle between 201 and 202.

incisor may also develop between, and so cause separation of the normal incisors (Fig. 8.7).

If just one or two supernumerary incisors are present that lie rostral (labial) to the normal incisor arch, it is usually possible to extract them following infra-orbital (or mental) nerve block in the sedated horse, and removal of the rostral alveolar wall with a curved osteotome, as described in detail in Chapter 20. Long gingival incisions over the reserve crown should be sutured more apically after repositioning remnants of the alveolar wall. The occlusal aspect of the wound is left open for drainage (Fig. 8.7). If supernumerary incisors are very rostrally displaced (especially in older horses) dental elevators can be inserted progressively deeper into their periodontal space to loosen them without removal of any alveolar wall.

Supernumerary incisors and possibly displaced normal incisors can erupt in an overcrowded manner along the normal incisor arch, and caudal (palatal) to them on the rostral aspect of the hard palate. In addition to the difficulty in clinically differentiating supplemental supernumerary incisors from normal incisors, it is usually very difficult to extract such displaced supernumerary incisors without causing damage to the remaining incisors, the hard palate and overlying soft tissues. Lateral and intra-oral radiographs generally demonstrate the great length of the reserve crowns of both the normal and the (indistinguishable) supernumerary incisors that are lying closely together, sometimes in an intertwined manner (Fig. 8.8). As the consequences of leaving multiple supernumerary incisors in are usually minimal, these teeth are, therefore, best not extracted. As the supernumerary incisors erupt, their occlusal surfaces are usually worn down by attrition – due to contact with food and intermittent contact with lower incisors due to the normal rostrocaudal movement of the mandible. If, however, supernumerary incisors are extremely displaced, individual teeth lose occlusal contact and overgrow. Such teeth should be reduced biannually, preferably using motorized equipment.

Supernumerary canine and 1st premolar teeth ('wolf teeth')

Supernumerary canine or 'wolf' teeth are rarely recognized, and most suspected supernumerary canine teeth are in fact rostrally displaced, large 1st premolar ('wolf teeth').¹⁶

Radiography readily differentiates these teeth from canine teeth by the size and shape of their reserve crowns and roots. Many suspected supernumerary 'wolf teeth' are retained fragments of the deciduous 06 that on closer inspection are seen to be a flat structure lying relatively superficially in the gingiva, as illustrated by Dixon and Dacre.²⁰

Supernumerary cheek teeth

The most common site for supernumerary CT development in horses is, as noted, the caudal aspect of the maxillary CT rows (Fig. 8.9) and less commonly, caudal to the mandibular 11s (Figs 8.10 & 8.11). These caudal CT have been termed Triadan 12s,¹⁶ but could also be termed Triadan 11b, if they originate from the same tooth bud as the normal 11. Supernumerary CT may also develop medial, lateral, or rostral to the upper or lower CT rows (Figs 8.12 & 8.13). Dixon et al illustrated a full-sized supernumerary maxillary CT lying in the physiological diastema (between the incisors and the 06),¹² and Wortley,²¹ and Dixon et al¹⁶ also reported supernumerary teeth developing in the hard palate, and further examples are shown in Figures 8.12 and 8.13. Usually just one or two additional CT develop, but Wortley reported a horse with four supernumerary maxillary CT.²¹ Many supernumerary CT erupt when the normal CT are erupting, but others may erupt in mature horses, and Dixon et al reported supernumerary CT eruption at 12 years of age.¹⁶ Connated supernumerary CT are very large and irregular in shape and consequently can displace adjacent CT. Their irregular interdental margins do not form tight seals with adjacent normal CT and the resultant large interdental (interproximal) space (i.e., diastema) leads to food pocketing and often painful periodontal disease.

In other instances where a caudal supernumerary tooth develops at the same time as the normal 11, overcrowding of the dental buds occurs prior to calcification. In these cases, the 11 and the supernumerary cheek tooth are both deformed and lie obliquely or possibly parallel to each other in separate or a common alveolus. Following eruption of the supernumerary cheek tooth, diastemata between these two distorted teeth allow food impaction also leading to painful periodontal disease. Unopposed caudal supernumerary CT will overgrow if not reduced (Fig. 8.11) and the overgrown teeth will become displaced caudally, causing diastema formation (Fig. 8.9).

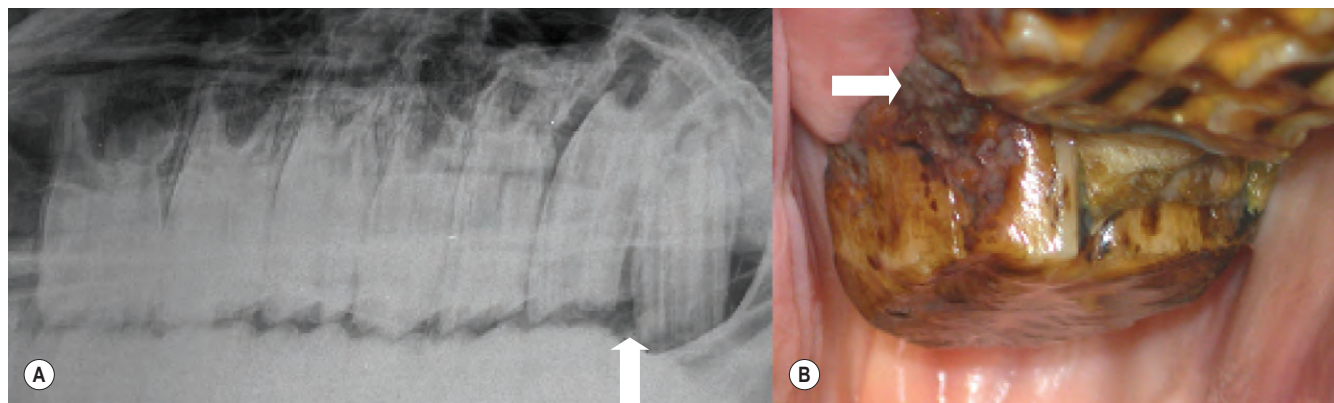


Fig. 8.9 (A) The supernumerary CT present at the caudal aspect of this maxillary CT row is overgrown due to absence of occlusal contact. Contact of the overgrowth with the caudal aspect of the lower 11 has caused it to displace caudally, causing a wide diastema (arrow) between it and the adjacent 11. (B) Intra-oral view of a supernumerary 212 that has overgrown and caused a diastema (arrow) to develop between it and the 211. The flat occlusal surface shows it has been reduced in the past.

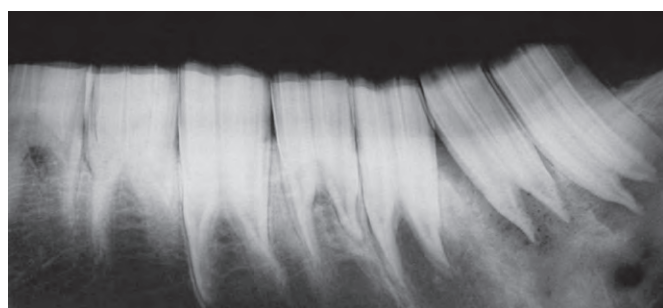


Fig. 8.10 Post mortem radiograph of a hemimandible with a caudal supernumerary CT. In addition, there are focal, lytic areas in the sclerotic mandibular bone under 311 associated with marked periodontal disease clinically evident around this tooth.

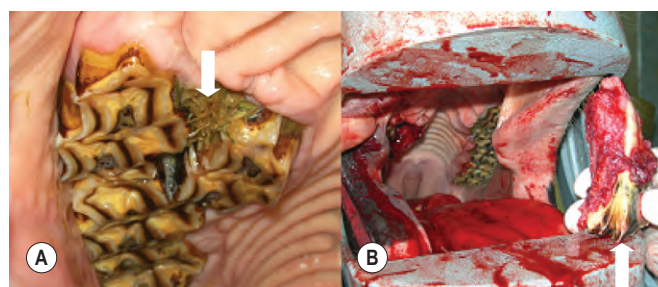


Fig. 8.12 (A) This supernumerary cheek tooth lies medial to 106/107 with much periodontal pocketing of food on its rostral aspect (arrow). (B) The periodontal disease has caused the darkened area on the crown of the orally extracted tooth (arrow).

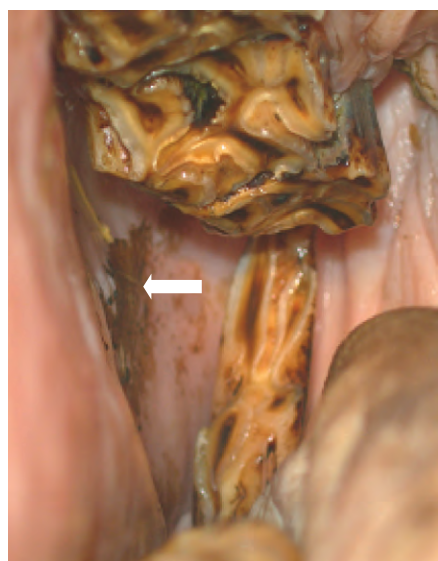


Fig. 8.11 A marked (circa 5 cm long) overgrowth is present on this caudally situated supernumerary mandibular CT (412) that has caused marked ulceration of the adjacent cheeks (arrow).



Fig. 8.13 A supernumerary maxillary CT lying medial (palatal) to 108 and 109 has caused some separation between these two normal teeth, with resultant diastemata formation and periodontal disease development between all three teeth. The subsequent marked and deep periodontal disease necessitated extraction of all three CT.

In the rare cases where clinically significant diastemata do *not* occur adjacent to a supernumerary cheek tooth, continuing eruption of the unopposed supernumerary tooth causes an overgrowth (usually at the caudal aspect of the CT rows) (Figs 8.9 & 8.11). Consequently, it is very worthwhile in horses with caudal CT overgrowths, especially with

unexplained development of such overgrowths, not to just assume that they are overgrowth of an 11, but to carefully count the teeth to assess if a supernumerary tooth is present. If any doubt exists, latero-oblique radiograph can confirm the presence of supernumerary teeth, but care must be taken not to mistake two overlapping teeth for a single, wide tooth. Very rarely, a second supernumerary tooth (e.g., Triadan 113) will develop caudal to the initial supernumerary cheek tooth as illustrated by Dixon et al.¹⁶

Careful examination of a well-restrained horse using a good light source and a dental mirror (or intra-oral camera) is needed to examine the poorly accessible caudal aspect of the mouth where supernumerary CT most commonly develop. If significant periodontal disease is present, extraction of the supernumerary tooth is the ideal solution, but this can be a very difficult procedure, especially in a young horse.^{16,22} Extraction of an upper 12 can be particularly difficult, as it will likely have a caudally facing reserve crown and apex that may partially lie beneath the orbit. Consequently, it is impossible to apply adequate repulsive forces directly behind the apex to repulse the supernumerary CT into the oral cavity, but careful application of lateral pressure may loosen the tooth.

For many reasons, oral extraction is preferable to repulsion, provided that enough clinical crown of a suitable shape is present, i.e., some supernumerary teeth may be conical – and very difficult to grip with extractors. Sometimes, caudal supernumerary CT may have been mechanically reduced (Fig. 8.9) and possibly rounded off on their occlusal surface, which may preclude oral extraction until they erupt further. Caudal maxillary supernumerary teeth lie beside and may be surrounded by the soft palate – whose normal boundary with the hard palate usually lies at the interdental space of the upper 10s and 11s. Consequently, great care must be taken when orally extracting caudal maxillary supernumerary CT to ensure that the soft palate is not damaged. In particular, it is essential that the soft palate is not perforated towards its midline (where there is no underlying rim of bony palate), as such oropharyngeal fistulas show poor tendency to heal and are likely to cause permanent dysphagia in affected horses. Extraction of CT is comprehensively discussed in Chapter 20.

If oral extraction is not feasible, and clinical signs of apical infection are not present (e.g., sinusitis – with presence of caudally situated supernumerary CT), a further option is to remove any overgrown crown causing soft tissue trauma, and, possibly, to attempt to widen the interproximal space between the supernumerary tooth and the normal 11s using a diastema burr in order to prevent food impaction at this site. Alternatively, any diastema and periodontal pockets present can be cleaned out and filled with acrylic or endodontic restorative material.²³ Due to poor access and commonly also to tongue movements, diastema widening is a relatively difficult procedure when the supernumerary tooth has erupted directly behind the 11, and great care must be taken not to damage the soft palate with the burr during the procedure.^{24,25} If the supernumerary and the Triadan 11 teeth have an obliquely oriented interproximal space between them, it is even more difficult to safely widen this diastema and constant monitoring with an intra-oral mirror or endoscope is necessary during the procedure to guide the diastema burr along the irregular interdental space. Additionally, due

to the potential great depth of the diastema (e.g., up to 7 cm deep), it may not be possible to clean them fully of impacted food, even with use of pressurized water or air systems.

As noted, diastema formation adjacent to a supernumerary Triadan 12 can lead to apical infection of the supernumerary and/or adjacent CT and to caudal maxillary sinusitis. Alternatively, food tracking (between the upper 11s and 12s) into the sinus may cause an oromaxillary fistula without apical infection of adjacent CT.²³ Unless advanced apical changes are present in such teeth, it may be difficult to determine the presence of apical infection by radiography alone because of the superimposed radiodense sinus structures and contents. Careful examination of each tooth for the presence of pulpar exposure is indicated in such cases and may indicate the presence of apical infection.^{26–28} Advanced imaging techniques, such as scintigraphy and computerized tomography, can also be of great value. In the absence of conclusive evidence of apical infection of the upper 11, extraction of the supernumerary tooth prevents further food pocketing and allows healing of the oromaxillary defect. In the presence of an oromaxillary sinus fistula, sinuscopy or sinusotomy is indicated with thorough lavage of food from the sinus and placement of a postoperative sinus lavage system. If the supernumerary CT is not apically infected, the placement of acrylic into the cleaned and prepared diastema may prevent further ingress of food into the sinus.²³ Careful reduction of supernumerary CT also helps prevent its caudal displacement and reduces the likelihood of loss of diastema packing and re-development of oro-maxillary fistula.

Dental dysplasia

Dysplasia or abnormal development of teeth can involve the crown, roots, or all of the tooth. Commonly recorded disturbances in the gross form of teeth include dilacerations (abnormal bending of teeth), double teeth, abnormalities of size, and concrescence (roots of adjacent teeth joined by cementum) of teeth.^{1,9} Disturbances in the structure of teeth, including dysplasias (disturbances of development) of the individual calcified dental tissues or pulp, are well described in human dentistry, with disturbances in amelogenesis particularly well described.²⁹ There is a rapidly increasing knowledge of the genetic defects that underlie some of these dental dysplasias.³⁰ However, very many human dental dysplasias are secondary to systemic diseases that can occur *in utero*, or during the neonatal or postnatal periods. Local disturbances, including trauma, can also cause dental dysplasia; for example, the most common cause of enamel hypoplasia of a single human permanent tooth ('Turner tooth') is damage to the developing ameloblasts by infection of the overlying deciduous tooth.⁹

Amelogenesis imperfecta includes a range of hereditary disorders affecting enamel formation in both deciduous and permanent teeth and can be divided into two types, i.e., defects in enamel matrix formation or in the mineralization of enamel. The genetics of this disorder in particular are well studied in human dentistry, with AMELX gene mutations increasingly described.^{9,30} Amelogenesis imperfecta as part of a generalized ectodermal syndrome has been described in a horse (Fig. 8.14),¹⁰ and an amelogenesis defect is also the



Fig. 8.14 Severe dental dysplasia with some abnormally small sized (microdontia) and misshapen CT, and concurrent hypodontia in a young Thoroughbred that suffered a generalized ectodermal dysplasia. (From Ramzan et al¹⁰ with permission from *Equine Veterinary Journal*.)

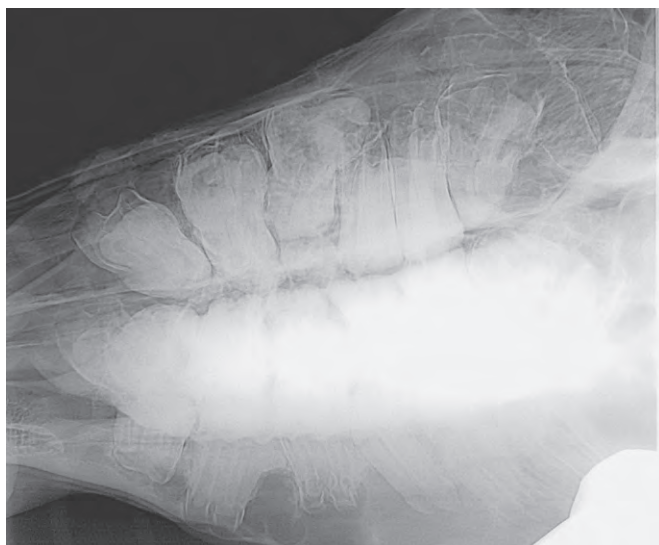


Fig. 8.15 Lateral-oblique radiograph of a 3-year-old horse that initially presented with maxillary sinusitis. Gross dysplasias of multiple permanent cheek teeth are present. (Image courtesy of Dr Scott Palmer.)

likely cause of the widespread dental dysplasia present in the horse shown in [Figure 8.15](#).

A wide range of developmental defects of dentin has been described in humans including dentinogenesis imperfecta and others caused by mineral and vitamin deficiencies. Developmental cemental defects are less commonly described in any species, and include root hypercementosis, a feature so commonly found in older equine teeth as to be almost regarded as physiological. Marked hypercementosis is present in some chronic equine CT apical infections.^{26–28} A dramatic hypercementosis of equine incisors has also been described in many horses affected with the recently described equine odontoclastic tooth resorption and hypercementosis syndrome.³¹

Examples of dysplastic incisors ([Figs 8.16 & 8.17](#)) and dysplastic cheek teeth ([Figs 8.14, 8.15, 8.18 & 8.19](#)) are also presented here. Recent studies have shown dysplasia to be a



Fig. 8.16 This recently erupted dysplastic 403 has an abnormal protrusion on its labial aspect.



Fig. 8.17 This young horse has displaced and abnormally shaped maxillary incisors that additionally are suffering focal enamel caries – a rare feature at this site, that is likely caused by structural developmental defects.

relatively common finding in apically infected CT, and to predispose to the apical infection in a minority of cases, and two examples are shown here ([Figs 8.20 & 8.21](#)).^{26–28} Some dysplastic teeth are of normal morphological structure and of normal shape but are excessively large i.e., **macrodontia** or too small, i.e., **microdontia**, and an example of the former is given in [Figure 8.21](#).

Disparity in the length of the cheek teeth rows

A disparity between the lengths of the upper and lower CT rows, including due to the presence of a supernumerary cheek tooth in one row, or because of larger CT in one opposing row, can result in overgrowths occurring unilaterally or bilaterally on the 06s or 11s (or supernumerary teeth) in upper or lower CT rows. Supernumerary CT problems are dealt with separately later in this chapter. The CT overgrowths should be reduced biannually (as earlier described for the craniofacial disorder, *rostral positioning of the maxillary CT row*) using techniques outlined in Chapter 17.

Abnormalities of dental eruption

Maleruption of cheek teeth

Some cases of 'stepmouth' and 'wavemouth' are caused by mismatched eruption of opposing permanent CT in the maxillary or mandibular rows,¹⁹ causing an overgrowth of the teeth that erupt first. Bilateral overgrowths of the upper 10s are a common pattern of this disorder in some



Fig. 8.18 (A) Lateral-oblique radiograph of a miniature Shetland pony with dysplasia of 109, 110 and 111. The large, abnormally curved (dilacerated) 109 has caused caudal displacement of the abnormally shaped 110 and 111, with resultant development occlusal abnormalities of both CT rows. (B) Dilacerated dysplastic tooth following extraction. The clinical crown had a groove cut in it to aid its extraction.

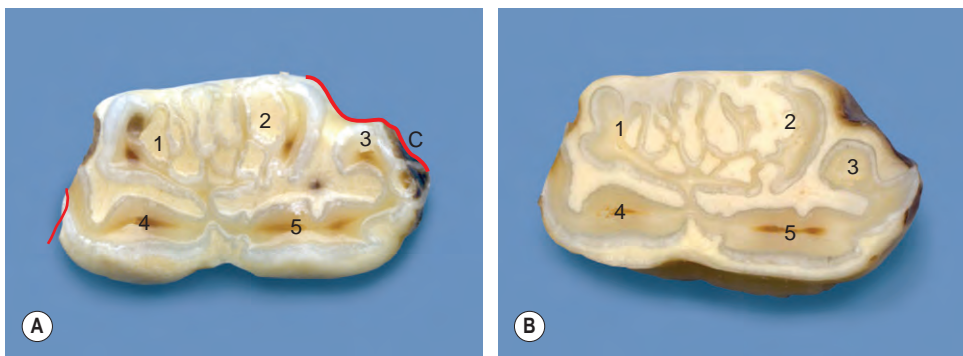


Fig. 8.19 (A) The occlusal surface of a 307 with multiple, branched subdivisions of pulp chambers 1 and 2 caused by dysplastic enamel. The dysplastic enamel has altered the overall shape of the tooth, causing it to poorly fit its alveolus, resulting in some localized periodontal food pocketing and periodontitis (site indicated by superimposed red lines). (From Dacre et al,²⁶ with permission from *The Veterinary Journal*.) (B) The mid-tooth section shows all pulp chambers to be empty. The enamel dysplasia has caused reduced dentinal thickness, and the peripheral cementum has become very infolded, appearing like maxillary infundibula, i.e., completely surrounded by enamel. A new cheek teeth pulp horn numbering system is now in use (see Chapter 5).

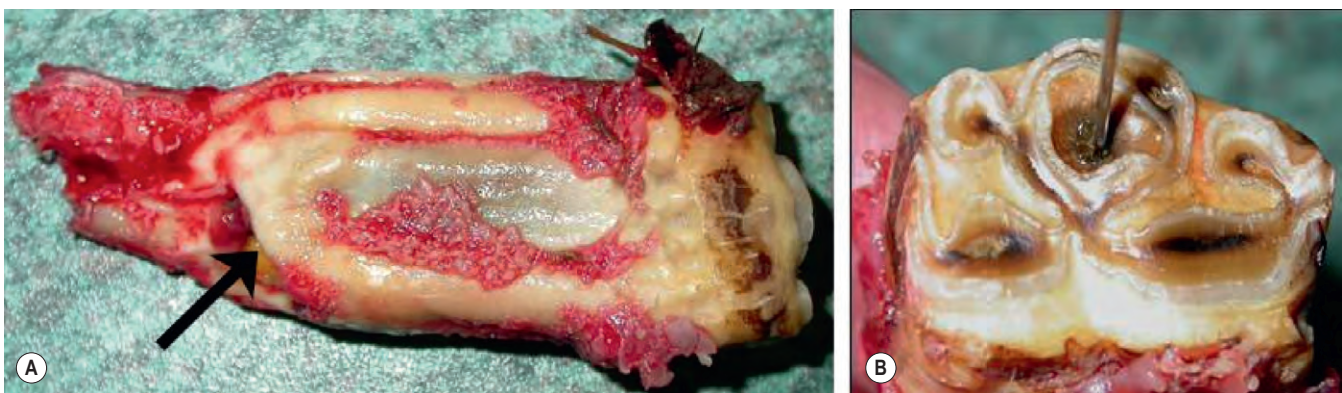


Fig. 8.20 (A) The caudal root of this dysplastic, apically infected mandibular CT is absent, and its site has a large apical opening leading into a wide necrotic pulp chamber (arrow). Some extraction-induced loss of periodontal membrane has occurred. (B) The occlusal surface shows an additional dysplastic pulp chamber (surrounded by a ring of enamel) that is occlusally exposed. (From Dacre et al,²⁶ with permission from *The Veterinary Journal*.)

breeds. These developmental overgrowths may remain for life and even increase in magnitude with time, initiating additional abnormalities of CT wear and diastemata. Recognizing and removing such overgrowths at an early stage (in stages if necessary) is the key to their successful management, as discussed in Chapter 17.

Retention of deciduous teeth

Retention of incisors

Deciduous incisors are occasionally retained for a significant period beyond their normal time of shedding, which is approximately 2.5, 3.5, and 4.5 years of age, respectively, for the 01s, 02s and 03s. Because the permanent tooth buds normally develop lingual (on oral aspect) to their deciduous precursors, retained incisors usually lie labial (rostral) to the erupting permanent incisors,¹¹ (Fig. 8.22) or lie between and displace the permanent incisors (Figs 8.23, 8.24) but rarely can develop on their lingual aspect (Fig. 8.25).³² Retained incisors can cause the erupting permanent incisors to be

displaced (usually lingually), and if deciduous incisors are retained for long enough (e.g., >1 year), they may cause lasting changes to the position of the permanent incisors.³³ In some horses, the permanent incisor erupts beside its deciduous precursor, thus forming an expanded incisor arcade. In such cases, it may be difficult to clinically differentiate between the normal permanent incisors and the retained incisor(s), or indeed to assess if the additional tooth in the arcade is in fact a supernumerary incisor. Consequently, radiographs should be taken prior to attempted extraction of any additional incisor, unless it can be positively identified on morphological appearance as being a retained incisor.

Under sedation and appropriate regional nerve block, firmly attached retained deciduous incisors with short reserve crowns can sometimes be extracted, using dental elevators and forceps. However, retained incisors with very long reserve crowns need resection of their alveolar wall to allow extraction. Deciduous incisors that are retained on the lingual aspect of the permanent teeth are more difficult to extract, and their reserve crowns may need to be ground (reamed) out.³² Details of incisor extractions are presented in detail in Chapter 20.



Fig. 8.21 This macrodontic (enlarged) 110 (arrows) is of normal appearance, but is about 50 % wider than the normal maxillary CT. Due to its large size, it has overgrown and excessively worn down the normal (but smaller) opposing 410.

Retention of cheek teeth

Abnormal retention of the remnants of the deciduous CT (termed 'caps') can occur in horses between 2 and 4.5 years of age. These deciduous teeth are normally shed at 2.5, 3 and 4 years of age respectively, for the 06s, 07s, and 08s, but there can be much individual variation in the timing of deciduous cheek tooth shedding.^{33,34} If the deciduous teeth are loose, they may abnormally stretch or tear periodontal ligaments or gingival attachments during mastication, causing short-term oral discomfort. Affected horses may display headshaking, quidding, resistance to the bit, and occasionally loss of appetite for a couple of days, until the loose teeth are shed. Such clinical signs of oral discomfort in 2–4-year-old horses warrant careful oral examination for evidence of deciduous teeth that are loose or have a distinct space between deciduous and permanent teeth (Fig. 8.26). If loose deciduous CT are found, they can be removed using specialized 'cap' extractors or small CT forceps (Fig. 8.27).



Fig. 8.22 (A) This retained 702 has caused caudal (distal) displacement of the permanent 302 and 303. (B) A ventrorostal view showing the 6-cm long tooth being extracted.

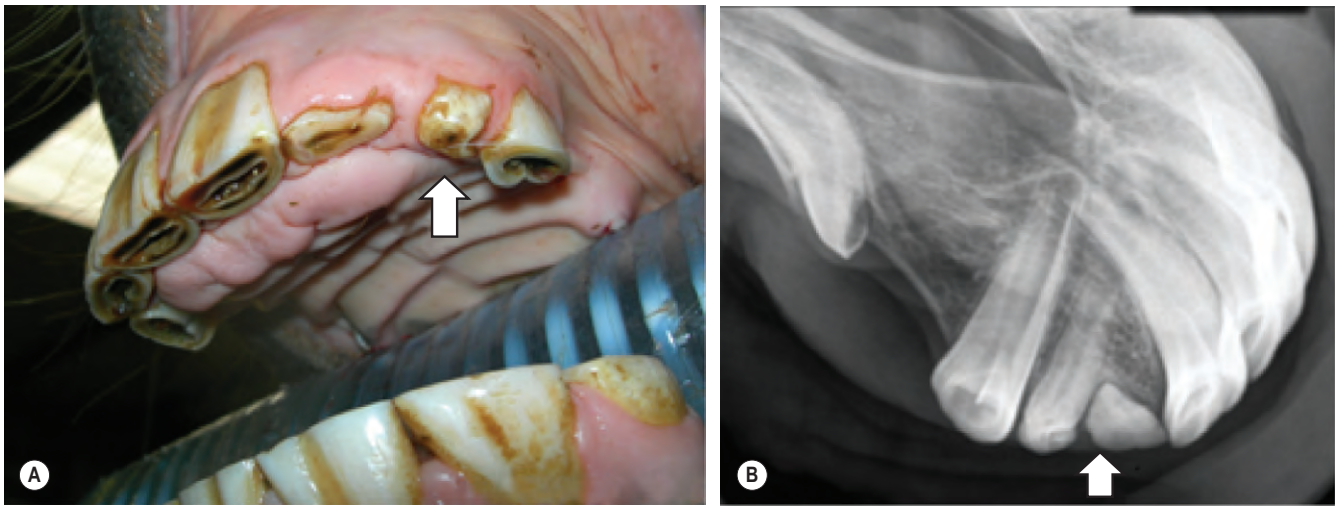


Fig. 8.23 (A) The additional incisor present in this maxillary incisor arcade was believed to be the tooth with a small rounded clinical crown (arrow), rather than the tooth with a normal sized crown medial (mesial) to it. (B) However, this radiograph showed a wide, short remnant of the 602 to be retained (arrow) and the tooth with the small, rounded clinical crown to be a (slightly small) permanent incisor (302).



Fig. 8.24 Retention of the deciduous 702 (arrow) has caused caudal (distal) displacement of the permanent 303 with subsequent abnormal wear of 303 and the opposing 203.

Even if not loose, some clinicians advise that temporary CT should be extracted, if the corresponding contralateral 'cap' has already been shed.

It has been suggested that the prolonged retention of 'caps' may predispose to delayed eruption of the underlying permanent cheek tooth and also to the development of enlarged 'eruption cysts' ('3 y.o. or 4 y.o. bumps') and thus to apical infections.³⁵ These swellings, beneath the developing apices of the permanent CT, occur more commonly on the mandible than maxilla. However, another study found no evidence of retained deciduous CT in horses with mandibular apical infection – most of which developed within months of eruption of affected teeth.³⁶ Nevertheless, there is close temporal relationship between dental eruption, and development of apical infection in mandibular CT.³⁶ The presence of very enlarged eruption cysts on a mandible or maxilla, especially if unilateral, should prompt a thorough oral examination for the presence of retained deciduous CT, or other dental abnormalities.

The practice of methodically removing deciduous teeth at set ages results in the premature removal of deciduous CT

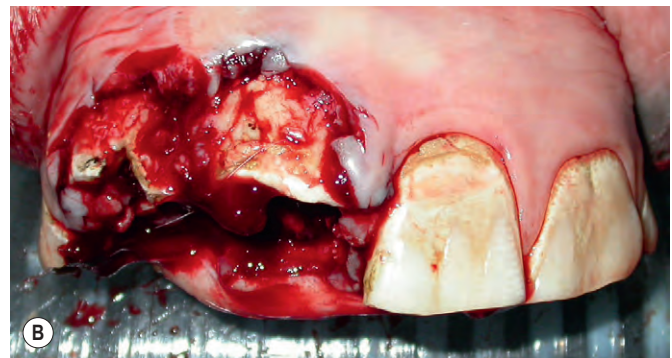


Fig. 8.25 (A) Initial examination of these incisors might suggest rostral displacement of two retained deciduous incisors (501, 502). However, radiography showed the rostrally displaced incisors to be the permanent teeth (101,102), with two short, retained deciduous incisors lying caudal (lingual) to them. (B) View of premaxilla following extraction of the two retained incisors.

in some horses. Once the deciduous tooth is removed, the fleshy dental sac covering the underlying developing permanent cheek tooth is exposed and quickly destroyed by mastication. This leads to loss of blood supply to the occlusal aspect of the infundibula of the rostral three upper CT (06, 07, 08), where active cement deposition may still be occurring. This may result in marked central infundibular cement hypoplasia and so predispose to the development of



Fig. 8.26 A distinct margin is apparent between the deciduous and permanent mandibular CT in this skull, indicating the former is ready to be shed, and is retained by periodontal attachments on one side only (arrow).



Fig. 8.27 This loose deciduous tooth, which had a large space between it and the underlying permanent CT with food entrapment, is being extracted with a 'cap extractor'.

infundibular caries later in life. In conclusion, deciduous teeth should not be removed until they become digitally loose; have an obvious space between them and the erupting permanent CT; protrude above the remaining occlusal surface; or the contralateral deciduous tooth has been shed.

Vertical impaction of cheek teeth ('eruption cysts'; '3 year-old and 4-year-old bumps')

As noted in the previous section, many horses develop focal, bilateral swellings of their mandible and also less obviously (due to the presence of overlying muscles) of their maxillae beneath the developing apices of the 07 and 08 CT (Fig. 8.28). Certain breeds, especially lighter breeds and miniature breeds in particular, are more prone to develop these bony swellings. These eruption cysts may be due to vertical impaction of the CT that erupt last and a study showed increased angulation of the two adjacent CT onto



Fig. 8.28 This 4-year-old horse has bilateral eruption cysts beneath the lower 07s and 08s.

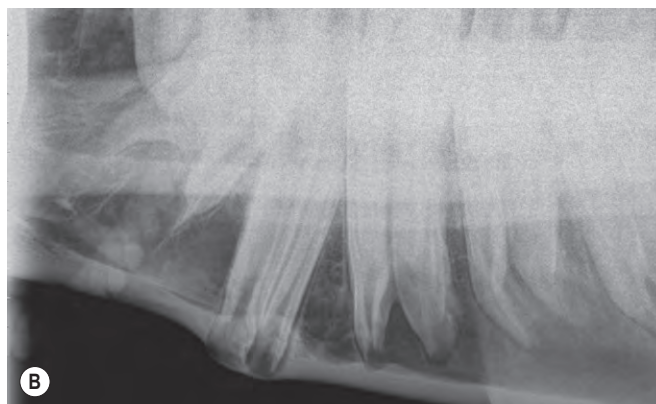
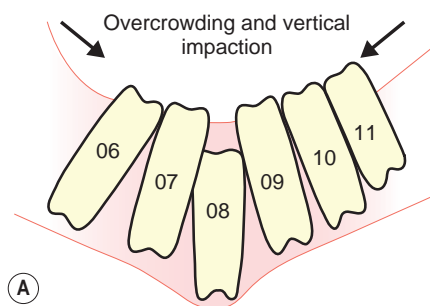


Fig. 8.29 (A) Diagrammatic representation of overcrowding and vertical impaction of a mandibular 08. (B) Radiograph of a vertically impacted 307 that has become ankylosed to the ventral mandibular cortex. Additionally, marked drifting of the two adjacent teeth (306, 308) more occlusally now permanently prevents its eruption.

mandibular CT with apical infection.³⁶ With time, as the mandible and maxillae lengthen, the impacted CT have room to erupt normally and the overlying bones then remodel to a normal contour over the following year or so. Occasionally, the impacted tooth may become ankylosed to the ventral mandibular cortex and never erupt (Fig 8.29).

Developmental diastema(ta)

As noted earlier, the occlusal surfaces of the individual CT rows are normally compressed tightly together so that the occlusal surface of the 6 CT in each row function as a single

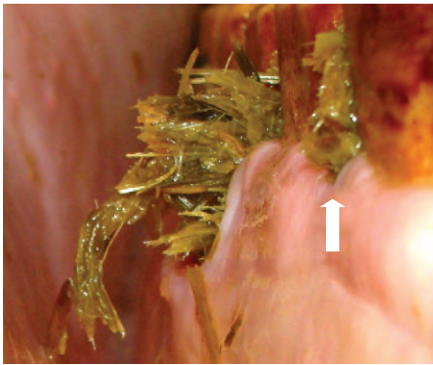


Fig. 8.30 View of medial aspect of the left hemimandible showing deep food impaction with periodontal disease in three interdental (interproximal) spaces that has been caused by CT diastemata.

grinding unit. However, if spaces, i.e., diastema(ta) develop in the interdental (interproximal) space between the CT, food impaction will occur in these spaces^{12,24,25} (Fig. 8.30). Developmental mechanisms that can allow CT diastemata to develop^{24,25} include inadequate angulation of the rostral (06s) and caudal (10s, 11s) CT that normally compress the occlusal aspects of all 6 CT together occlusally. Alternatively, CT may have normal angulation but develop too far apart due to disparity between size of teeth and supporting bones or because the CT buds develop too far apart.

Carmalt has proposed that the term *valve diastema* be used to differentiate these pathological diastemata from the normal diastemata present between the incisors (or canine teeth in males) and the CT (i.e., 'bars of mouth') or from a wide interdental space, e.g., where a cheek tooth has been lost.⁴ Such valve diastemata are more problematic than *open diastemata* – where the abnormal space has similar width from the occlusal surface to the gingiva. Du Toit et al have shown that clinical examination of diastemata can accurately differentiate between valve diastemata (narrower on occlusal than gingival aspect) or open diastemata (same width from occlusal to gingival aspects) – with mean occlusal to gingival diastema width ratios of 0.4 found in valve diastemata and of 1.07 in open diastemata.³⁷ The presence of sharp transverse overgrowths or accentuated transverse ridges directly opposite *wider* diastemata can selectively widen such diastemata and compress food into them, but most problematic CT diastemata are valve diastemata with narrow (<3 mm) spacing occlusally, that do not have linear occlusal overgrowths on the opposite CT.

The massive and prolonged forces of mastication on equine CT occlusal surfaces cause progressively deeper impaction of long fibers into widened interdental spaces, which can later spread sub-gingivally to the lateral and medial aspects of the two affected teeth. This leads to a painful and usually progressive secondary periodontal disease with remodeling and lysis of the alveolar bone – that occasionally may even lead to extensive osteomyelitis of the supporting mandibular or maxillary bones,¹² or if involving the upper 08s–11s, to sinusitis or an oro-maxillary fistula – with the overlying maxillary sinuses becoming filled with food and exudate.²³ CT diastema can be recognized by finding food fibers packed in between teeth and more significantly in periodontal pockets between the CT just above

the gingival margin (Fig. 8.30), especially between the caudal mandibular cheek teeth (09s–10s; 10s–11s). Due to their common position between the caudal mandibular CT where they are hidden by the tongue, mandibular CT diastemata are difficult to detect clinically unless these sites are carefully examined with an intra-oral mirror²⁴ or endoscope.^{38,39}

Open-mouthed radiographic evaluation of diastemata is a very useful method of assessment of this disorder, both to evaluate the dimensions of diastemata and more importantly, to assess the positions and angulations of the CT.^{40,41} Cheek teeth with good angulation may grow together over the following years, with closure of the diastemata, whilst the prognosis is poorer for CT with inadequate angulation.²⁵

Cleaning out periodontal pockets with manual dental picks or long, right-angled forceps, or by using high pressure water or air picks can allow short-term relief, and filling the cleaned periodontal pockets with soft plastic impression material may be of longer-term benefit for some cases. If present, removal of overgrown transverse ridges opposite diastemata may reduce food impaction. Feeding mechanically chopped forage is also palliative because short (e.g., <5mm long) fibers do not become entrapped in diastemata. In younger horses, this diet may allow time for further eruption and compression of the CT row, *provided* the rostral and caudal CT have sufficient angulation.²⁴ Specialized burs can be used to widen diastemata at the occlusal surface to help limit food trapping and are best used after radiographic evaluation (open-mouth projections) of diastemata and careful examination of the occlusal surface to assess the direction of the interproximal space (and diastema) between affected CT, as some (especially caudally situated) diastemata have a diagonal and/or wavy interproximal space. Great care must be taken not to thermally damage or directly expose the pulp of the CT being burred. A long-term study showed excellent clinical results with this treatment.²⁵

Developmental displacement of teeth

Displacement of incisors

In addition to displacements in the presence of supernumerary incisors, occasionally gross displacement of permanent incisors can occur in horses with a normal number of teeth (Fig. 8.31). Previous trauma can cause displacements of the developing incisors, especially mandibular incisor(s), but incisors may also be displaced because of intrinsic developmental reasons.

Displacement of cheek teeth

Displacements are extremely rare in deciduous equine CT, but are well recognized in permanent CT. Two different types of permanent CT displacement (i.e., developmental and acquired) are recognized in horses.¹² Most severe CT displacements, especially in younger horses, are developmental and often appear to be caused by overcrowding of the dental rows during eruption and, less commonly, by developmental displacement of the developing CT bud. Developmental CT displacement may be bilateral, and displaced CT may be bent (dilaceration), suggesting that dental overcrowding occurred prior to calcification of the developing tooth



Fig. 8.31 This 4-year-old horse has a developmental displacement of 202 that is rotated almost 90° and so is horizontally (rather than vertically) aligned to the long axis of the premaxilla. It was treated by repeated floating its occlusal surface. Extraction of the displaced incisor would be difficult and likely to damage the adjacent normal incisors.



Fig. 8.33 Post mortem image of a marked developmental lateral (buccal) displacement of a 309 that has not been treated for years. The displaced tooth has caused severe ulceration and deeper muscle damage to the cheeks (arrow). Marked periodontal disease on both sides of the displaced CT caused additional oral pain to this neglected horse. (From Dixon et al,¹² with permission from *Equine Veterinary Journal*.)

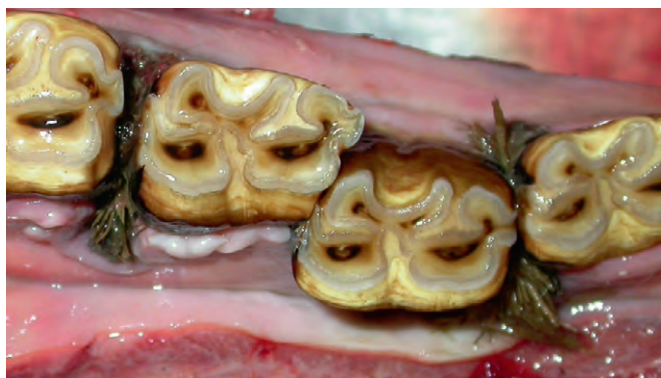


Fig. 8.32 Developmental displacement is present in this 410 which is bent. Diastema is present adjacent to the displaced tooth and also between 408 and 409.

(Fig. 8.32). Trauma to the jaws can also damage or displace a developing CT bud, causing later maleruption. The permanent 06, 07, and 08 positions are seldom affected with overcrowding or developmental displacements because they replace deciduous teeth of approximately the same size.

The 09 and 10 positions are most commonly displaced, and equine mandibular CT are three times more likely to be displaced than maxillary CT.¹² Rotation of displaced CT is occasionally present, especially with displaced maxillary CT. Large and sharp overgrowths can develop on aspects of displaced teeth and their opposing teeth, that are not in full occlusal contact. Developmentally displaced CT invariably

have diastemata between the displaced and adjacent CT (Fig. 8.31–8.33), which allows painful food pocketing.^{24,25} In some horses, very wide diastemata occur beside displaced CT, which suggests that abnormal positioning of the developing tooth bud, rather than dental overcrowding, was the initial cause of the displacement. Abnormally protruding areas of displaced CT and, less commonly, secondary overgrowths on opposite teeth, can lacerate the cheeks and tongue, causing biting and quidding problems (Fig. 8.33). However, deep and painful periodontal food pocketing due to concurrent diastemata is the usual cause of quidding that persists after the protruding areas of displaced (or opposing) teeth are ground down.

Marked displacements where CT lay horizontal in the mandible or the maxilla and never erupted have been reported.^{42,43}

Abnormal protrusions or overgrowths of displaced CT (or their misaligned opposing CT) can be removed with manual or power instruments, and impacted food in diastemata should be removed. If very extensive food pocketing is present, these diastemata can be mechanically widened (removing most dental tissue from the displaced tooth), and overgrowths on the opposing teeth ground down. Finally, displaced teeth can be extracted, especially when markedly displaced or rotated, and this procedure is most readily performed in older horses with shorter reserve crowns, especially where the CT have been loosened by deep periodontal disease. Such extractions can readily be performed per os in the standing, sedated horse, and an excellent clinical response usually follows.

References

1. Miles AEW, Grigson C. Colyer's Variations and diseases of the teeth of animals. Cambridge University Press, Cambridge, 1990, pp 118–122, 307–311
2. Easley J. Basic equine orthodontics. In: Baker GJ, Easley J, eds. *Equine dentistry*, 2nd edn. Elsevier, Edinburgh, 2005, pp 249–266
3. Easley J. Equine orthodontics. In: *Focus on Equine Dentistry*, American Association of Equine Practitioners, Indianapolis, 2006, pp 39–46

4. Carmalt JL, Townsend HGG, Allen AL. Effect of dental floating on the rostrocaudal mobility of the mandible of horses. *Journal of the American Veterinary Medical Association* 2003; 223: 666–669
5. Scrutchfield WL. Equine dental instrumentation. In: Baker GJ, Easley J, eds. *Equine dentistry*, WB Saunders, London, 1999, pp 173–184
6. Easley J. Corrective dental procedures. In: Baker GJ, Easley J, eds. *Equine Dentistry*, 2nd edn. Elsevier Saunders, Edinburgh, 2005, pp 221–248
7. Brown SL, Shaw DJ, Dixon PM, Arkins S. Occlusal angles of cheek teeth in normal horses and horses with dental disease. *The Veterinary Record* 2008; 162: 807–810
8. Schumacher J, Dixon PM. Diseases of the Nasal Cavity. In: McGorum BC, Robinson NE, Dixon PM, Schumacher J, eds. *Equine Respiratory Medicine and Surgery*, Elsevier Oxford, 2005, pp 369–392
9. Soames JV, Southam JC. Disorders of development of teeth and craniofacial abnormalities. In: *Oral Pathology*, 4th edn. Oxford University Press, Oxford, 2006, pp 1–18
10. Ramzan PHL, Dixon PM, Kempson SA, Rossdale PD. Dental dysplasia and oligodontia in a Thoroughbred colt. *Equine Vet J* 2001; 33: 99–104
11. Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease part 1: a long-term study of 400 cases: disorders of incisor, canine and first premolar teeth. *Equine Vet J* 1999; 31: 369–377
12. Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease part 2: a long-term study of 400 cases: disorders of development and eruption and variations in position of the cheek teeth. *Equine Vet J* 1999; 31: 519–528
13. Wafa NSY. A study of dental disease in the horse. MVM thesis, National University of Ireland, Dublin, 1988, pp 91–173
14. Baker GJ. A study of equine dental disease. PhD Thesis, University of Glasgow, 1979, pp 36–38
15. Orsini PG. Oral cavity. In: Auer JA, ed. *Equine Surgery*, WB Saunders, Philadelphia, 1992, p. 300
16. Dixon PM, Easley KJ, Ekmann A. Supernumerary teeth in the horse. *Journal of Clinical Techniques in Equine Practice* 2005; 4: 155–161
17. Rajab LD, Hamdan MAM. Supernumerary teeth: review of the literature and a survey of 152 cases. *International Journal of Paediatric Dentistry* 2002; 12: 244–254
18. Garvey MT, Barry HJ, Blake M. Supernumerary Teeth – An overview of classification, diagnosis and management. *Journal of the Canadian Dental Association* 1999; 65: 612–616
19. O'Connor JJ. Affections of the teeth: Abnormalities of development. In: O'Connor JJ, ed. *Dollar's Veterinary Surgery*, 4th edn. Alexander Eger, Chicago, 1950, p. 591
20. Dixon PM, Dacre I. A review of equine dental disorders. *Vet J* 2005; 169: 165–187
21. Wortley AJ. Irregularities and diseases of the teeth. In: Wortley AJ, ed. *The horse, its treatment in health and disease*, Vol.2. Gresham Publishing, London, 1907, p. 327
22. Dixon PM, Dacre I, Dacre K, et al. Standing oral extraction of cheek teeth in 100 horses (1998–2003). *Equine Vet J* 2005; 37: 105–112
23. Hawkes CS, Easley J, Barakzai SZ, Dixon PM. Treatment of oromaxillary fistulae in nine standing horses (2002–2006). *Equine Vet J* 2008; 40: 546–555
24. Collins N, Dixon PM. Diagnosis and management of equine diastemata. *Techniques in Equine Practice* 2005; 4: 148–154
25. Dixon PM, Barakzai S, Collins N, Yates J. Treatment of equine cheek teeth by mechanical widening of diastemata in 60 horses (2000–2006). *Equine Vet J* 2008; 40: 22–28
26. Dacre IT, Kempson S, Dixon PM. Pathological studies of cheek teeth apical infections in the horse Part 4: Aetiopathological findings in 41 apically infected mandibular cheek teeth. *Vet J* 2008; 178: 341–351
27. Dacre IT, Kempson S, Dixon PM. Pathological studies of cheek teeth apical infections in the horse. 5 Aetiopathological findings in 57 apically infected maxillary cheek teeth and histological and ultrastructural findings. *Vet J* 2008; 178: 352–363
28. van den Enden MS, Dixon PM. Prevalence of occlusal pulpar exposure in 110 equine cheek teeth with apical infections and idiopathic fractures. *Vet J* 2008; 178: 364–371
29. Aldred MJ, Crawford PJ. Amelogenesis imperfecta – towards a new classification. *Oral Diseases* 1995; 1: 2–5
30. Vastardis H. The genetics of human tooth agenesis: new discoveries for understanding dental anomalies. *American Journal of Orthodontics and Craniofacial Orthopaedics* 2000; 117: 650–656
31. Staszky C, Bienert A, Kreutzer R, et al. Equine odontoclastic tooth resorption and hypercementosis. *Vet J* 2008; 178: 372–337
32. Alexander K, McMillen RG, Easley J. Incisor extraction in a horse by a longitudinal forage technique. *Equine Veterinary Education* 2001; 13: 179–182
33. Scrutchfield WL, Schumacher J. Examination of the oral cavity and routine dental care. *Veterinary Clinics of North America – Equine Practice* 1993; 9: 123–131
34. Sisson S, Grossman JD. In: *The Anatomy of Domestic Animals*, 4th edn. WB Saunders, Philadelphia, 1971, pp 396–405
35. Barrairon P, Blin PC, Molinier F. Contribution à l'étude du mécanisme de formation de fistule des prémolaires chez le jeune cheval. *Bulletin de l'Académie Vétérinaire de France* 1980; 53: 47–54
36. Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease part 4: a long-term study of 400 cases: apical infections of cheek teeth. *Equine Vet J* 2000; 32: 182–194
37. Du Toit N, Burden FA, Gosden L, Dixon PM. A study of the dimensions of diastemata and associated periodontal food pockets in donkey cheek teeth. *J Vet Dent* 2009; 26: 10–14
38. Tremaine WH. Dental endoscopy in the horse. *Clinical techniques in equine practice* 2005; 4: 181–187
39. Simhofer H, Griss R, Zetner K. The use of oral endoscopy for detection of cheek teeth abnormalities in 300 horses. *Vet J* 2008; 178: 396–404
40. Easley J. A new look at dental radiography. In: *Proceedings of the 48th Annual Convention of the American Association of Equine Practitioners*, 2002, pp 412–420
41. Barakzai SZ, Dixon PM. A study of open-mouthed oblique radiographic projections for evaluating lesions of the erupted (clinical) crown. *Equine Veterinary Education* 2003; 15: 143–148
42. Edwards GB. Retention of permanent cheek teeth in horses. *Equine Veterinary Education* 1993; 5: 399–402
43. Becker E, Zahne. In: Dobberstein J, Pallaske G, Stunzi H, Band V, eds. *Handbuch der speziellen pathologischen anatomie der haustiere*, 3rd edn. Verlag Paul Parey, Berlin, 1962, pp 121–265

Head and dental trauma

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A variety of injuries affecting the oral cavity may be encountered in equine practice. Many of these injuries arise from inquisitive or playful interaction of the horse with objects in its environment. Other injuries are the direct result of human action. Oral injuries may involve, in various combinations, the soft tissues, osseous, and/or dental structures of the mouth.

The oral environment and healing of oral injuries

Although wounds within the oral cavity are exposed to food material and a large mixed resident population of obligate and facultative anaerobic and aerobic bacteria, healing generally proceeds far more rapidly than with cutaneous wounds. Even extensive intra-oral injuries to the cheeks or tongue rapidly resolve providing the inciting cause (fractured or displaced tooth, foreign body, or sequestrum) is no longer present. One of the factors responsible for such efficient healing and the limited subsequent formation of scar tissue, is that oral mucosal wounds have a subdued inflammatory response compared to external skin wounds.^{1,2} In addition, the constant bathing of oral wounds with saliva (rich in protease inhibitors, cytokines and growth factors) also speeds up wound healing. Furthermore, an excellent oral vascular supply ensures that tissue devitalization is minimal.

Given the intrinsic good healing characteristics of the oral mucosa, there is generally little merit in attempting to assist healing by using topical medications, and in any event, there is little objective support for the efficacy of most such treatments. Oral lavage with a saline solution or water may temporarily assist in reducing contamination with food material. Similarly, unless wounds are full-thickness or closure is necessary to prevent food contamination of deeper defects, suturing of intra-oral injuries is not generally indicated.

Management of horses with facial trauma

A horse with major facial trauma should be assessed immediately for the presence of life-threatening respiratory obstruction, epistaxis, and any indication of other major dysfunction, such as neurological or ocular disturbance.

Maintenance of a patent airway must be a priority and if required, insertion of an emergency tracheotomy tube should be carried out without delay. Most nasal hemorrhage (from nasal cavity and/or sinuses) associated with facial injury ceases without need for particular action. Secondary infection of the paranasal sinuses is common following facial fracture and appropriate antibiotics should be administered. Sinus lavage may also be of benefit with an open fracture of the sinus walls, or where there has been significant intrasinus hemorrhage. In horses with major facial wounds, the extent of osseous or dental injury and the presence of radiodense foreign bodies should be assessed using multiple radiographic projections or, if available, computed tomographic (CT) imaging, before any attempt is made to repair the overlying soft tissues.

Management of specific intra-oral injuries

Lips and cheeks

One of the most commonly encountered injuries to the lips is traumatic injury to the commissures of the lips arising from the use of a bit. Damage to the soft tissues may occur directly from inappropriate pressure on the bit or as a result of soft tissue being trapped between the bit and the rostral cheek teeth. The appearance of these injuries is determined by severity and chronicity, ranging from a fresh wound to ulceration and eventually to scar tissue formation. To facilitate healing it is sensible to remove the inciting cause, which can mean a period of time without using a bit. This is often impractical and minimizing ongoing soft tissue trauma must then be the primary goal. The use of a wide rounded bit such as a rubber snaffle and removal of sharp cheek tooth edges, can assist in the prevention of lip and cheek damage. Rounding the profile of the rostral aspect of the 06s (first maxillary and mandibular cheek teeth), known as 'bit-seating', may also be employed. Any such profiling should be performed with awareness of the possibility of exposing the rostral (6th) pulp and thus causing pulpitis if reductions are excessive. If large, displaced or sharp wolf teeth are present and felt to be contributing to the problem, their extraction may also be indicated.

Abrasions or lacerations of the cheeks within the oral cavity can arise from direct trauma to the soft tissues by sharp or prominent buccal enamel points/edges or displaced



Fig. 9.1 A small fresh buccal ulcer adjacent to a maxillary cheek tooth.

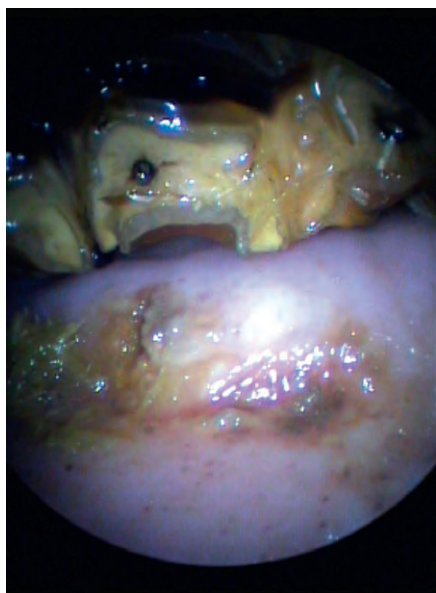


Fig. 9.2 Chronic buccal abrasion of dental origin.

or fractured teeth. Injuries may be detected, when acute, as mucosal lacerations or fresh abrasions (Fig. 9.1) or when chronic (characterized by ulceration with thickened mucosal edges or scar tissue; Fig. 9.2). The removal of the inciting cause usually resolves the problem.

Trauma to the external lip or muzzle is usually the result of the horse biting or playing with a fixed object in its environment. These injuries are typically full thickness, and although wound breakdown often ensues, an attempt at sutured repair is usually indicated to maximize the chance of a good cosmetic and functional outcome. Following lavage of the wound and debridement of any obviously devitalized tissue, a multi-layer repair of the defect is usually undertaken (Fig. 9.3) beginning with apposition of the oral mucosa with simple interrupted or continuous absorbable sutures. External closure of the skin wound using non-absorbable suture material or staples then follows. However, with more extensive defects, separate closure of the muscular layer should also be performed with absorbable sutures to afford the best chance of healing by primary intention. It may be beneficial to minimize excessive movement at the

suture line by separating the adjacent musculature at the edges of the wound, thus reducing the chance of dehiscence. Should the sutured wound subsequently partly or fully dehisce, it may be left to heal by second intention. If cosmetic or functional outcome is poor, secondary repair of the wound can be undertaken at a later date.

Tongue

There are two main types of direct injury to the tongue that are encountered in practice. Lacerations of the lateral margins of the tongue (Fig. 9.4) may be caused by the horse inadvertently biting itself, trauma from displaced or fractured teeth or from a foreign body. Injuries to the tongue arising from inappropriate restraint may also be encountered. In the latter case, aggressive use of a leading bit (typically a chifney) can result in laceration of the dorsal or lateral margins of the rostral portion of the tongue. These injuries can range from small superficial cuts to near-total transection of the tongue (Fig. 9.6). Occasionally, a horse is examined that has previously sustained a severe laceration of the tongue that has healed, leaving a large defect in its dorsum or lateral border (Fig. 9.5). Grasping the tongue as a means of restraint can also result in injury should the handler fail to release the tongue if the horse pulls back; excessive traction can cause laceration of the lingual frenulum. It is not usually necessary to repair these injuries.

Horses that have sustained a laceration of the tongue due to dental or foreign body trauma at the back of the mouth typically present with acute signs of oral discomfort and excessive salivation. A thorough examination of the oral cavity, using a full-mouth speculum, is necessary to assess these injuries. Due to their hidden location, some caudal lacerations of the tongue may be more readily detectable by digital examination, rather than by direct visualization. However, oral endoscopy, if available, is the preferred technique to image the caudal tongue and a dental mirror may also reveal some such lesions. Care should be taken to palpate the dorsal and both lateral margins of the base of the tongue, particularly at the level of the occlusal surface of the mandibular cheek teeth. Once the inciting cause is removed, these injuries tend to heal without further intervention, although anti-inflammatory and/or antibiotic therapy may be beneficial in some cases. On occasion, focal abscess formation or more generalized infection of the tongue may occur following foreign body penetration (often with food material, wire fragments, or wood splinters). Such cases may present with signs of oral discomfort and excessive salivation; however, early diagnosis is often more difficult than for the lacerations discussed above. In these cases, the tongue is often grossly normal to visualisation without use of endoscopy, but palpation of the affected site may reveal an area of firmness within the softer body of the tongue, which elicits a pain response on digital pressure and which may be associated with focal malodour. Depending on the severity of clinical signs, aggressive treatment with broad-spectrum antibiotics or surgical drainage of a lingual abscess may be necessary.

In the case of a severe, bit-induced laceration of the tongue (Fig. 9.6), assessment of the wound (and tongue viability) is often best performed under general anesthesia. A gauze bandage tied around the tongue caudal to the wound can be

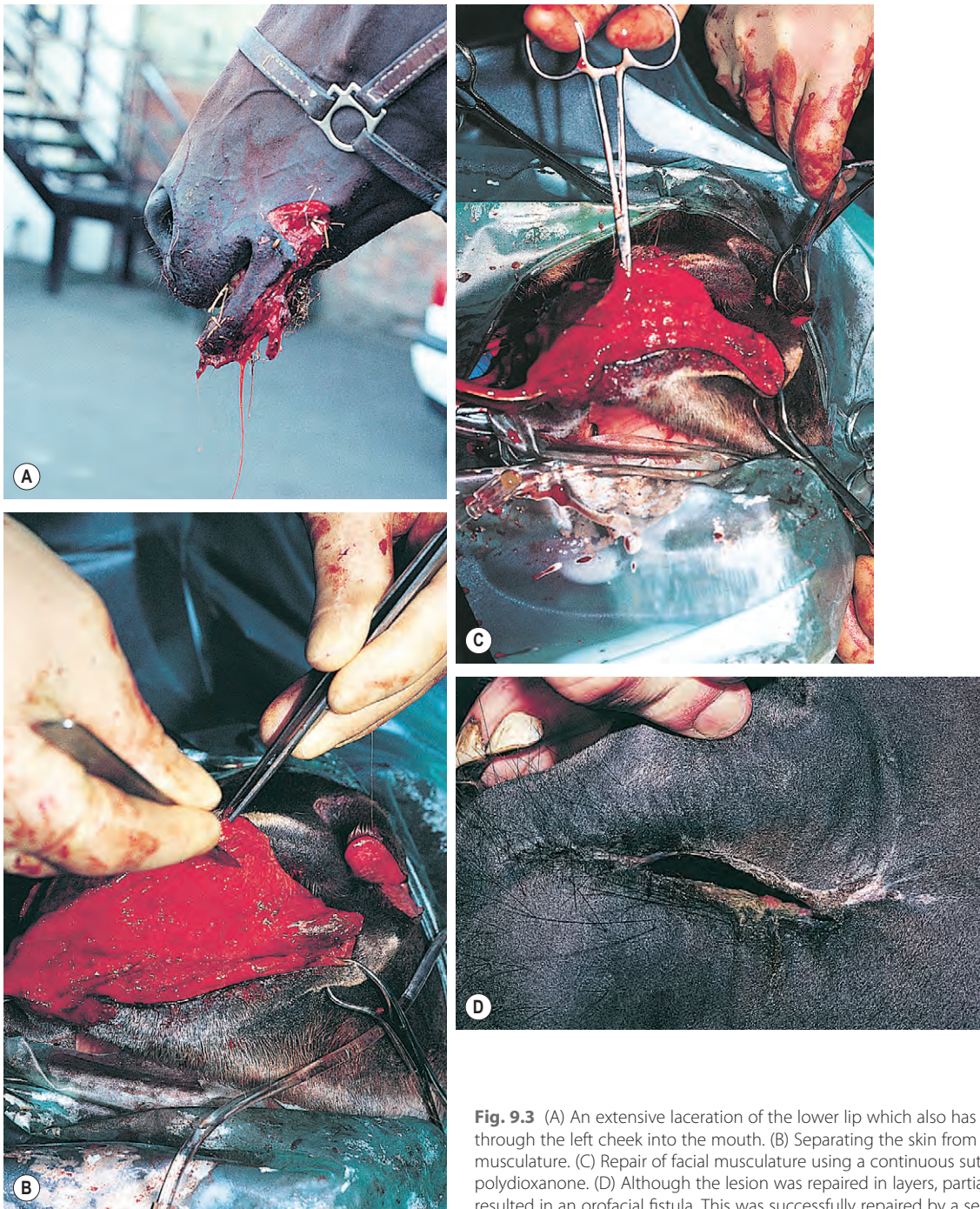


Fig. 9.3 (A) An extensive laceration of the lower lip which also has a full-thickness defect through the left cheek into the mouth. (B) Separating the skin from the underlying musculature. (C) Repair of facial musculature using a continuous suture of 4 metric polydioxanone. (D) Although the lesion was repaired in layers, partial wound dehiscence resulted in an orofacial fistula. This was successfully repaired by a second operation.

used as an effective tourniquet. Gentle traction to the bandage also allows good exposure of the more caudal parts of the tongue. Glossectomy may be necessary if the tongue tip is considered unviable (Fig. 9.7), and removal of tissue up to the level of rostral attachment of the frenulum is unlikely to affect function. Intravenous administration of sodium fluorescein has been recommended as an aid to assess tongue viability. Oversewing the body of the tongue with simple interrupted or a continuous suture of polyglactin 910 or polydioxanone should be attempted after removal of the necrotic tip. Severe lacerations are repaired using simple interrupted and vertical mattress sutures applied

alternately (Fig. 9.8). The latter should incorporate a significant bulk of lingual musculature to take up some of the tension and to ensure more satisfactory healing. All dead space should be obliterated if possible.

Multiple-layer closure of thicker areas of the tongue may be required. It should be remembered that the tongue is very mobile, and the risk of wound dehiscence is significant unless care is taken to align the tongue correctly and to repair the injury accurately. If the injury is not dealt with immediately, some necrosis and a high level of wound contamination may occur. In such circumstances, all devitalized tissue must be debrided carefully to minimize the risk of wound

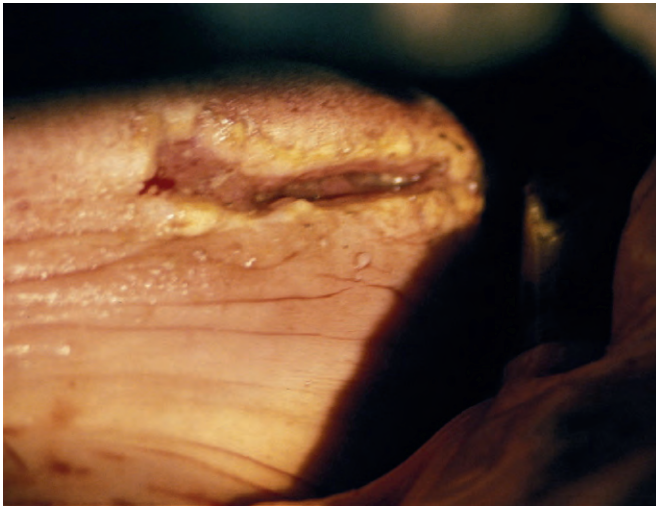


Fig. 9.4 Large healing lingual laceration caused by self-trauma.



Fig. 9.5 Healed lingual laceration involving all of dorsum.



Fig. 9.6 This severely lacerated tongue has been severed almost completely. The injury was repaired using simple interrupted sutures of 4 metric polydioxanone alternated with vertical mattress sutures of the same material. The wound healed by primary intention, and the horse regained normal use of its tongue.

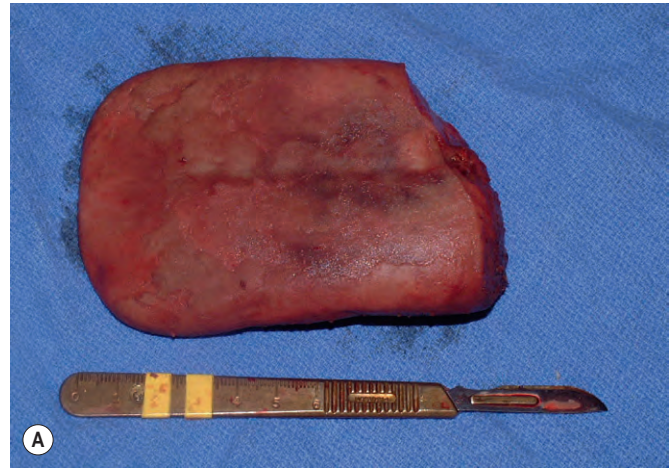


Fig. 9.7 (A) Amputation of severely lacerated tongue. (B) Stump of amputated tongue.



Fig. 9.8 Severely injured tongue repaired using polydioxanone sutures.



Fig. 9.9 Oropharyngeal foreign body.

dehiscence. When placing vertical mattress tension sutures care must be taken to avoid damage to the lingual blood supply. Although this blood supply is good, vascular compromise may result in necrosis of the more rostral aspects of the tongue, particularly when the tip is involved. The dorsum of the tongue has a much stronger mucosa than its ventral aspect, and suture retention is better in this site. Tension sutures should, therefore, be placed in this area.

Oropharynx

Lesions at the base of the tongue and in the oropharynx are difficult to evaluate visually, by palpation or imaging, and are also difficult to surgically repair due to their inaccessibility. Diagnosis is best achieved by oral endoscopy. Fortunately, these inaccessible wounds usually heal well without the need for surgical repair. Daily lavage of the oral cavity with a saline solution may be of value in reducing wound contamination with food material. This site is also prone to damage by ingested foreign bodies, which are usually twigs or pieces of wood. In most circumstances, affected horses show a sudden onset of oral discomfort, dysphagia, inappetence, excessive salivation, and occasionally, epistaxis. Foreign bodies within the oropharynx (**Fig. 9.9**) can often be detected by nasopharyngeal endoscopy as they frequently protrude through the intrapharyngeal ostium. Foreign bodies can usually be retrieved manually with the horse under heavy sedation or general anesthesia. Repair of any mucosal injury is usually unnecessary.

Ulceration of a caudal pharyngeal soft tissue pillar is a not uncommon sequel of dental 'floating'. The soft tissues at this site are in very close proximity to the occlusal surface of the caudal mandibular cheek teeth (**Fig. 9.10**). Trauma may occur if excessive caudal movement of the rasp blade occurs during manual rasping of the last mandibular cheek tooth (311, 411), or if soft tissue becomes trapped between the tooth and rasp blade or motorized burr. Ulceration can vary in severity, and although clinical signs are generally self-limiting, affected horses may demonstrate oral dysphagia until healing occurs, which can be days or even weeks later.



Fig. 9.10 Close proximity of caudal soft tissue pillar to occlusal surface of last mandibular cheek tooth (tooth 311).



Fig. 9.11 Oblique radiographic image showing mandibular sequestrum.

Systemic antibiotic and anti-inflammatory therapy is indicated with more severe injuries.

Mandibular interdental space ('bar' or 'physiological diastema')

Injuries to the dorsal (intraoral) aspect of the mandibular interdental space (mandibular 'bar') are invariably caused by damage from a bit. Aggressive use of a bit, or indirect, blunt, bit-related trauma, such as when a loose horse treads on trailing reins, may result in damage to one or both mandibular bars. In the most severe cases, the injury may cause a mandibular fracture (see **Fig. 13.47** in Chapter 13). However, more often with recent injuries there is ulceration/laceration of the overlying gingiva that is painful to pressure, and the horse resents further biting. If the damage is superficial, these injuries will heal unaided, providing time is allowed without bit contact. In a small proportion of cases, the dorsal cortex of the bone underlying the damaged mucosa may become devitalized and subsequent sequestrum formation (**Figs 9.11 & 9.12**) can result in a chronically discharging and painful focus. Radiographic



Fig. 9.12 This is an oral ulcer in the interdental space of the right mandible of a horse which suffered an injury following restraint with a chifney. A large sequestrum can be seen, which was removed. The horse made a complete recovery.

examination (oblique lateral projections) and/or ultrasonographic examination may be necessary to confirm the presence of a sequestrum. If a sequestrum is identified, surgical removal is necessary if healing is to be expected, and this can be performed satisfactorily with the horse sedated and using regional (subgingival) analgesia. A longitudinal incision of the gingiva overlying the affected area permits the introduction of a bone curette which is used to elevate the sequestrum. Primary closure of such surgical sites is unnecessary and ridden work using a bit may resume once the mucosa has healed completely.

Hard and soft palates

Injuries to the hard palate are rare but may accompany severe head trauma (Fig. 9.13). In some circumstances, there may be an underlying fracture of the palatine processes of the premaxillary and/or the maxillary bones. In general, these injuries can be left as open wounds, to heal by second intention. However, if the hard palate injury has caused an oronasal fistula, such lesions should always be repaired surgically. A suspected oronasal fistula may be confirmed by a combination of thorough clinical and endoscopic examinations, and by radiography after oral administration of barium sulfate. While such a fistula may heal by second intention, surgical repair should be attempted if the site is accessible. It may be possible to repair the defect by debriding the wound and curetting any area of oronasal mucosal continuity and simply suturing the palatal mucosa with interrupted, polydioxanone sutures (Fig. 9.14). If the injury cannot be



Fig. 9.13 This horse sustained severe trauma to the maxilla which resulted in a fracture of the premaxillary bone and laceration of the hard palate. There was direct continuity between the oral and nasal cavities.

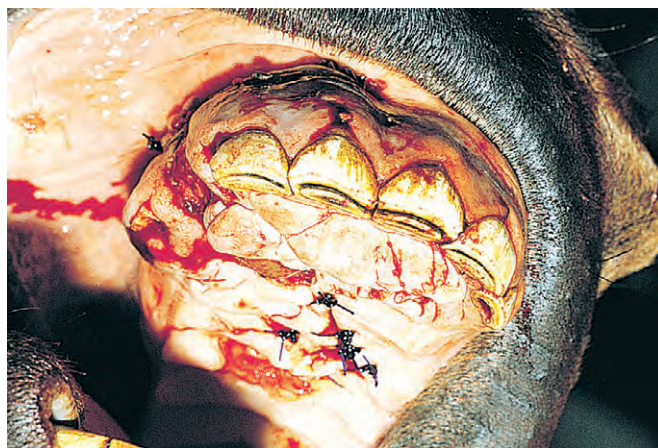


Fig. 9.14 This is the surgical repair of the injury illustrated in Fig. 9.13. The fracture has been reduced with cerclage wire after radical debridement of the site. The palate has been sutured partially using simple interrupted and vertical mattress sutures of 4 metric polydioxanone. The horse made an uneventful recovery, and the cerclage wire was subsequently removed.

repaired adequately in this manner, it may be possible to close the defect by creating a mucoperiosteal flap, or by making tension-relieving incisions in adjacent portions of the palate and then suturing the defect. Care should be taken to avoid damaging the palatine blood supply. Post-repair feeding should be carried out by nasogastric intubation for the first 4 or 5 days to reduce the risk of suture dehiscence. If the rostral portion of the skull is grossly unstable following a maxillary or premaxillary injury, the fractures may require surgical repair. However, it is surprising how frequently horses with such major injuries respond successfully to conservative management.

Iatrogenic injuries to the hard palate are uncommon but usually arise from dental intervention. The greater palatine artery courses close to the palatal margin of the maxillary cheek teeth. Inadvertent laceration may occur during 'wolf' tooth removal or intra-oral extraction of a cheek tooth, and profuse hemorrhage ensues. This hemorrhage is dramatic but rarely life-threatening and is usually effectively controlled by pressure. If the defect is large enough it may

be possible to insert and suture in place some gauze bandage packing. The affected horse should be kept in a quiet environment until bleeding subsides. If the horse is sedated, it is useful to keep its head very elevated on a headstand. Lacerations of the hard palate mucosa may also arise iatrogenically from the use of dental extraction forceps during oral extraction procedures, but such injuries typically heal by second intention without intervention.

Injuries to the soft palate are uncommon but may result iatrogenically from surgical procedures involving the soft palate or adjacent structures, such as surgical correction of epiglottal entrapment. When attempting to axially divide the displaced mucosa using a curved bistoury, the soft palate may become inadvertently damaged. However, there are new safer knives available to avoid such risks. Injuries may also arise from the use of motorized dental instrumentation, particularly during procedures to reduce overgrowths of the caudal mandibular or maxillary cheek teeth. In the case of large overgrowths (such as with supernumerary maxillary cheek teeth), the soft palate may 'billow' around the tooth during swallowing, and damage may ensue unless particular care is taken and equipment incorporating a soft-tissue guard or clutch is used. The soft palate may also be lacerated by extraction forceps during oral extraction of a caudal maxillary (especially a caudal supernumerary) cheek tooth.

Full-thickness injuries to the soft palate inevitably result in the development of an oronasal fistula because of contamination with food and saliva. Whilst some of these defects heal by second intention, surgical repair should be attempted as soon as possible after the injury has been identified. Access for surgical repair is very limited, especially in smaller horses and ponies. A general anesthetic should be administered and an oral speculum used to permit access to the mouth. Good lighting (e.g., a head light) should be provided, and the area should be endoscopically examined to assess the extent of the injury. Long-handled retractors should be used to depress the base of the tongue and retract the cheeks in order to evaluate the injury and assist in its subsequent repair. Long-handled needle holders, forceps and scissors are also of great help when attempting repair of such an injury. Separating the oropharyngeal mucosa from its overlying musculature will facilitate soft palate closure in two layers, enhancing the likelihood of achieving first intention healing. The musculature and nasopharyngeal mucosa are closed as one, and the oropharyngeal mucosa as the other. Simple-continuous sutures using polydioxanone for each layer are preferred.

Even though such defects may be closed effectively, and initially appear to be healing well, dehiscence is common some days or weeks later. This is because of the high mobility of the palate for very prolonged periods during mastication and deglutition, and the presence of food and saliva within the oral cavity and oropharynx. It is not unusual for second and even third attempts at repair of full-thickness palatal defects to fail. However, small fistulae may heal spontaneously. As described above, feeding such cases by nasogastric intubation for some days postoperatively is important to reduce the risk of dehiscence of the suture line. Similarly, this method of feeding helps in the conservative management of such a fistula and should be combined with muzzling of the patient, in an attempt to reduce contamination of the airway by food and bedding material.



Fig. 9.15 This horse developed a salivary fistula, which caused saliva to flow out under pressure during eating (arrow) following damage to the parotid duct during surgical treatment of a chronic mandibular infection.

Salivary tissue

Injuries to the salivary glands usually occur as a result of direct trauma. The parotid gland is the most vulnerable because of its large size and superficial location behind the angle of the jaw. Such injuries can be repaired by wound debridement, cleansing, and closure of the skin. Salivary cutaneous fistulae are rare after this sort of injury.

Injuries to the parotid duct at more rostral sites are more common and usually associated with direct trauma to the ventral border of the mandible, which the duct crosses beneath before entering the oral cavity. In some cases, there may be little evidence of an injury to the duct, and there may be no need for specific treatment as such wounds may readily heal spontaneously. However, in a proportion of cases, there is direct continuity between a ruptured salivary duct and a skin wound that may result in the development of a salivary facial fistula (Fig. 9.15). Such injuries often have the dramatic consequence of creating a profuse discharge of saliva during eating and mastication. Although saliva tends to have an inhibitory effect on healing, most of these wounds eventually close within 1–2 weeks, without need for specific treatment. It is the authors' practice to manage all parotid duct fistulae conservatively in the certain knowledge that in the vast majority of cases the fistula heals uneventfully.

In those unusual cases in which the fistula does not close, surgical repair may be effective. The duct should be dissected from the edge of the fistula and closed with simple interrupted sutures of 2-metric polyglactin 910. Insertion of a catheter into the parotid duct may facilitate accurate suturing. Injury to the parotid duct may occur inadvertently during facial or dental surgery. However, an understanding of the local anatomy should preclude such an occurrence. Transection of the parotid duct may be performed electively when carrying out a buccotomy technique for removal of mandibular or maxillary cheek teeth. In such cases, an end-to-end anastomosis can be carried out using simple interrupted sutures of 2 metric polyglactin 910. A parotid duct fistula may follow surgical removal of sialoliths, which are occasionally encountered in older horses. Secondary closure of such wounds may be effective or, alternatively, they may be left to heal by second intention.

Injuries to the mandibular or sublingual salivary glands or ducts are very rare. The authors have encountered one horse with a ranula associated with the sublingual salivary duct that was managed successfully by oral marsupialization.



Fig. 9.16 Radiographic projection to highlight the temporomandibular joint.

Temporomandibular articulation

Despite its superficial location, traumatic injuries to the temporomandibular joint are rare. On occasion, an open wound is encountered with direct communication to the joint; these cases are typically presented for treatment some time after initial injury, usually due to non-healing of the wound. Thorough assessment of the injury using skyline radiographic projections³ (Fig. 9.16; or preferably by computed tomography if available) and ultrasonography is essential when planning treatment. Debridement of the wound and lavage of the joint are performed under general anesthesia and aided by arthroscopy, followed by post-surgical wound management and antibiotic therapy. This usually results in successful resolution of the articular sepsis; however, some masticatory dysfunction may be a long-term sequel. Mandibular condylectomy and meniscectomy with a successful outcome have also been described and are an option for cases with severe or longstanding injury.⁴ Further details of temporomandibular disease are presented in Chapter 23.

Management of mandibular and maxillary fractures

Rostral mandibular fractures

Fractures of the rostral mandible are the most common type of jaw fracture sustained by horses.^{5,6} Such injuries typically arise from play behavior with or biting of stable furniture such as bucket handles, rack chains, window bars, and mangers and are most common in young horses. Although they are invariably contaminated and often dramatic in appearance, appropriate management usually results in good functional and cosmetic repair.⁷ Aside from some protrusion of the lower lip and scant hemorrhage, there is often little outward sign of injury. Oral pain tends not to be a feature, and affected horses are often found eating with little



Fig. 9.17 Rostral mandibular fracture impacted with food.



Fig. 9.18 Traumatic avulsion of 402 and 403.

sign of discomfort; indeed most fractures are already heavily contaminated with food material when first examined (Fig. 9.17). The injury typically comprises partial avulsion of one or more incisor teeth with a variable amount of associated bone. Fractures typically range from simple loss or loosening of a single (usually corner) incisor tooth and its labial alveolar bone plate, to more extensive or complex fractures involving a single fragment accommodating several incisor teeth or several fragments. The fractured portion of the mandible is usually displaced ventrally, with a gingival or mucosal wound on the floor of the mouth communicating with the open fracture (Fig. 9.18). Bilateral fractures are less common (Fig. 9.19).

Near-complete avulsion of a single tooth with only gingival or minimal bone attachment may be dealt with by removal of the avulsed tooth by sharp dissection of the remaining gingiva, but most other types of injury warrant an attempt at reduction. Unless obviously devitalized, teeth should be left *in situ*, as removal can take place at a later date, if necessary. As these fractures often occur in young (1–2-year-old) horses, the avulsed teeth are usually deciduous incisors and thus the loss of any severely avulsed teeth is of minimal, long-term consequence. In contrast, the fracture often involves the dental sacs of developing permanent



Fig. 9.19 Rostral mandibular fracture with two fragments.

incisor teeth, and every effort should be made to retain these, given that their loss or disruption causes eventual maleruption of the permanent dentition.

Radiography may be unnecessary for the assessment of some simple rostral mandibular fractures because the choice of repair technique is determined by the clinical presentation of the fracture rather than by its radiological appearance. Radiography is much more important for horses with bilateral or comminuted rostral mandibular fractures which usually require a more complicated repair. Surgical reduction may be performed in the standing sedated patient, aided by bilateral regional analgesia of the mandibular nerves within the mental foramina, or under general anaesthesia. Following lavage and gentle curettage of the fracture, satisfactory reduction is usually possible with relative ease. The objective of fracture repair is to re-establish anatomical alignment (to optimize cosmetic and functional outcome) and to stabilize the fracture fragments. Whilst some rostral mandibular fractures heal without surgical intervention, healing in such cases is often delayed and almost invariably results in long-term disfigurement of the incisor arcade.

Fracture reduction in the young horse can usually be achieved through placement of single or multiple intra-oral tension wires attaching the avulsed portion to the caudal interdental space of the contralateral aspect of the mandible. Wires can be inserted via appropriate holes in the mandible drilled with a 2.7- or 3.2-mm Steinmann pin held in a hand chuck (Fig. 9.20) or by using an air drill (Fig. 9.21). Canulation of the holes with a 14-gauge needle facilitates placement of the wire between teeth. A 14-gauge needle may be pushed through the softer mandibular bones of young foals without prior drilling of holes. At the completion of the procedure, the wire should pass through the fracture fragment, across the floor of the mouth, through the contralateral mandibular diastema then around the labial aspect of the rostral mandible (Fig. 9.22). The exact positioning of the anchoring holes will vary depending on fracture configuration and individual anatomical features. Wires are pressed digitally into the floor of the mouth to remove as much 'slack' as possible and to ensure they impinge as little as possible on the tongue. The ends are then brought together on the labial aspect of the mandible at a site distant to the fracture. Once the wire has been tightened and cut, it is

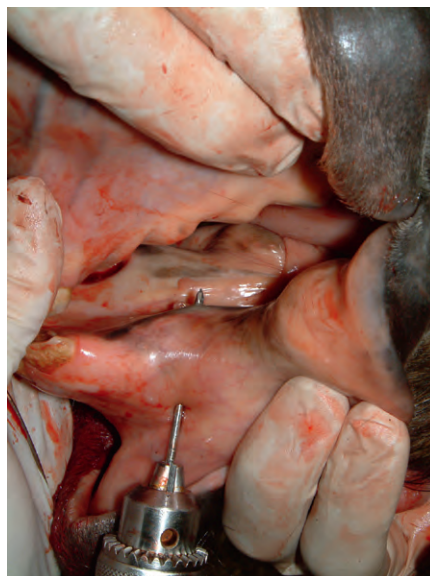


Fig. 9.20 Using a Steinmann pin to create a hole in the mandibular bone.



Fig. 9.21 Using a drill guide to protect soft tissues.

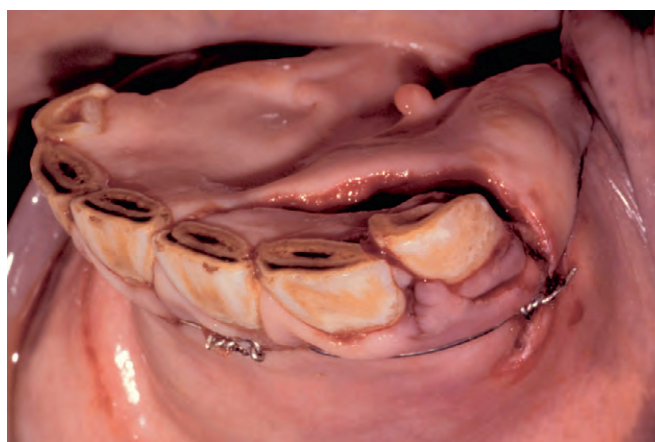


Fig. 9.22 Simple rostral mandibular fracture stabilized.

necessary to protect the adjacent soft tissues from the sharp ends of the knot. A small amount of silicon polymer dental impression material, or acrylic bone cement can be affixed to the wire knot; alternatively, the tips of the wires can be sheathed with plastisol covers, which prevent labial abrasion.



Fig. 9.23 Removing wire from a jaw fracture repair.

Suturing large mucosal lacerations may prevent continued gross contamination of the fracture site but is not necessary in most cases. Postoperative lavage (with a saline solution or even tap water b.i.d or t.i.d) is recommended to prevent food accumulation in any large oral defects for the few days it takes for satisfactory granulation of the wound to occur. However, despite the contaminated nature of many of these fractures, the incidence of significant postoperative infections is very low. It is not usually necessary to make any significant dietary alterations following repair for a simple rostral mandibular fracture. However, hay should be pulled apart and fed loose from the ground or chopped so the horse does not have to prehend with the repaired teeth. Typically horses show little sign of having sustained an injury and bitted ridden work can resume unless signs of pain are observed. If a bit is to be used it should always be inserted very carefully. Wires should ideally remain in place for 6–8 weeks. Removal of the wire is usually simple in the standing sedated animal (*Fig. 9.23*). The visible oral portion of the wire is first cut with wire cutters, then the knot on the labial aspect of the jaw is grasped and pulled firmly, drawing the entire implant from the jaw.

With good surgical reduction, complications are rare. The major long term adverse consequence of a fracture of the rostral mandible is malalignment of the incisor arcades. Disruption or loss of permanent incisor tooth germs can result in a failure of some teeth to erupt, or to erupt in inappropriate positions. Occasionally, a permanent incisor tooth is noted erupting in the floor of the mouth, beside the original fracture line, although this sequel is usually of cosmetic importance only. Other sequelae include scarring of the gingiva and incisor diastema formation.

Fractures of the interdental space (diastema)

Fractures through the interdental space may be unilateral or bilateral. Unilateral fractures usually arise from direct trauma, but pathological fractures secondary to longstanding osteomyelitis/apical dental infection are not unknown. Bilateral mandibular fractures are common in foals, and unilateral fractures more typically occur in older horses.



Fig. 9.24 An oblique interdental fracture.

Treatment of traumatic, unilateral, hemimandibular fractures is usually unnecessary as the unaffected hemimandible acts as a splint to ensure relative stability of the fragments and therefore good fracture healing. Clearly, complete bilateral fractures result in major instability of the rostral portion of the mandible. Such fractures are usually transverse or short oblique in configuration, and have minimal comminution (*Fig. 9.24*). Fractures of the maxillary interdental space are by comparison much less common but may involve comminution and some degree of nasal obstruction. In addition to premaxillary fractures, there may be concurrent fracture of the nasal septum, nasal process, facial bones or hard palate. A full radiographic series, including dorsoventral, lateral and oblique views, is indicated to delineate the fracture(s), and to identify involvement of adjacent teeth and osseous fragments. Computed tomography, if available, provides comprehensive characterization of the fracture configuration.

Repair of fractures of the interdental space is performed under general anesthesia. Intravenous anesthesia or nasotracheal intubation increases working space for the surgeon in the oral cavity, permitting the surgeon access both sides of the mandible. If surgical repair of a maxillary fracture is to be attempted, a standard orotracheal intubation is usually performed.

Methods of fixation of fractures of the interdental space include tension-band wiring, oral acrylic splints, U-bars, external fixators, and bone plating. Minimally displaced, unilateral fractures often have sufficient interdigitation at the fracture site to limit movement and pain and usually respond well to conservative therapy, which is the authors' preferred option in most cases. However, non-displaced fractures of the interdental space may be repaired using tension-band wiring. The tension surface of the mandible lies along the dorsal border (oral surface) allowing tension-band wiring to



Fig. 9.25 Premaxillary fracture repaired with cerlage wire.

be successful when minimal displacement is present. Minimally displaced fractures through the maxillary interdental space are rare and almost always bilateral. They have been successfully managed using a conservative approach, but such fractures also can be stabilized with tension band wires (Fig. 9.25) or an external fixation device.

Repair of bilateral interdental space mandibular fractures involves placing the anesthetized horse in dorsal recumbency; the oral cavity, left and right external cheek surfaces are then prepared for surgery. Holes are drilled between mandibular incisors as described previously. To repair rostral mandibular fractures, stab incisions are made bilaterally through the gingiva immediately caudal to the 06 (2nd premolar teeth). For more caudally situated mandibular fractures, horizontal stab incisions are made externally in the cheeks at a site between the 07s and 08s (second and third mandibular premolar teeth). Hemorrhage is minimized by using blunt dissection to separate underlying soft tissues. The buccal mucosa is incised, and a 3.2-mm drill bit is positioned between the 07 and 08 teeth just ventral to the gingival margin. Soft tissues are protected during drilling by use of a drill guide. Wire is threaded through the holes between the premolar teeth and directed rostrally to be interwoven through openings previously made between the incisors. Differing patterns for wire placement may be used incorporating one or two wires. The wire spanning the interdental space is twisted together to achieve compression at the fracture site. The stab incisions through the cheeks are left to heal by second intention or closed with a single suture. The wires are removed 6–8 weeks after fixation.

Intra-oral acrylic splints can also provide stable fixation of interdental space fractures and are technically easy to use.⁷ Following induction of general anesthesia and preparation of the oral cavity and cheeks, the fracture is reduced. Polymethylmethacrylate or cold-curing acrylic is mixed and

molded to fit the oral surface of the mandible or premaxilla, extending from the incisors to the 06, taking care to avoid the frenulum of the tongue. A thickness of 6–8 mm is sufficient for most splints; the acrylic may be thickened at sites of wire incorporation to reduce fatigue and thus breakage of the splint. The splint is removed after curing and rough edges are smoothed with files. Multiple, 1.2-mm-diameter wire loops are placed through holes drilled into both sides of the mandible or premaxillae between the incisors and in the interdental space, rostral and caudal to the fracture line. The splint is drilled to match the holes in the mandible or maxillae and the wires are twisted together and bent down into the gingiva. Wire loops may also be placed around the 06s (second premolar teeth) to provide caudal anchorage. Holes for these wires are placed as described above for tension-band wiring. Alternatively, the methylmethacrylate splint can be formed over preplaced tension band wires between the incisors and premolars. This technique allows the fracture to be reduced completely before application of the splint.

Intra-oral acrylic splints require minimal surgical invasion of the mandible, avoid the risk of damage to dental buds or apices and provide fixation on the tension side of the fracture. Acrylic splinting can be used successfully in foals with inadequate incisor eruption for placement of wires. In foals, a wire loop can be passed around the mandible in the diastema as an additional anchorage point for the splint. Care should be taken to pass the wire close to the bone to avoid compression and necrosis of the soft tissues, although any gingival damage resolves rapidly after wire removal. The oral cavity should be flushed daily and the splint removed 6–8 weeks after surgery, in the standing, sedated patient.

Although intra-oral placement of U-bars with fixation around the teeth using wire has been described⁷ to treat bilateral fractures of the interdental space, there are simpler methods of repairing such unstable fractures. There have been reports of using intra-oral orthopedic plates screwed to the teeth which seem to have been effective. Both techniques have the obvious drawback of involving a relatively large intra-oral device.

A simpler approach involves the use of long AO cortical screws drilled into either the mandible or premaxilla to fix lateral acrylic bars (Fig. 9.26). This simple technique has proven valuable to repair unstable fractures of the interdental space (R. J. Payne, unpublished data). A 3.2-mm drill is used to create holes through stab incisions in the gingiva or cheeks (as described above) at several appropriate sites rostral and caudal to the fracture on both sides of the head. Pre-drilled flexible tubing is threaded onto the long cortical screws before their incomplete implantation in the jaw. The screws are left protruding clear of the jaw to accommodate the tubing, which is then filled with acrylic material. This material rapidly cures to create a very stable fixation of the fracture on either side of the jaw. This method avoids the presence of implants within the oral cavity and is as effective as proprietary external fixation devices or the use of transmandibular Steinmann pins, which have also been used to stabilize such fractures by attaching them to laterally applied acrylic bars (Fig. 9.27).

The implants occasionally break but can usually be replaced without requiring a second general anesthetic. The device is usually removed in the sedated patient at



Fig. 9.26 External fixation for a bilateral mandibular fracture.



Fig. 9.27 Maxillary fracture treated with acrylic U bar.

approximately 6–8 weeks postoperatively. The screw holes usually heal faster than those created by transmandibular Steinmann pins.

Fractures of the caudal mandible

Fractures involving the horizontal ramus in the region of the molar teeth are typically unilateral with minimal displacement or comminution (Fig. 9.28). They typically arise from external trauma, such as a kick injury or fall, but iatrogenic fractures arising from dental repulsion procedures are also encountered. Aside from painful mastication, clinical signs may be non-specific. Thickening of the horizontal ramus may be noted, both externally and upon intra-oral examination; this may be subtle and tends to be generalized rather

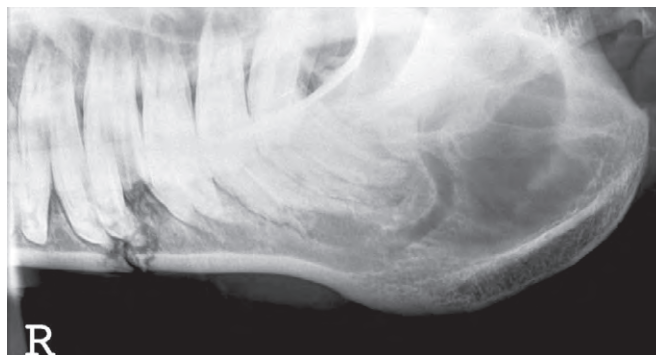


Fig. 9.28 Fracture of horizontal ramus involving a tooth.

than the focal thickening seen with dental apical infection. Close examination of the oral cavity may also reveal some mucosal bruising in the region of the fracture line and on occasion there is concurrent (usually transverse) fracture of an adjacent cheek tooth.

While fractures of the mandibular body (horizontal ramus) are seen occasionally in our hospital, those of the vertical ramus are very uncommon, in contrast to other authors' findings.⁸ The extent of the fracture and the possible involvement of teeth, temporomandibular joints, or even the hyoid apparatus should be assessed using multiple radiographic projections or computed tomography, if available. Such imaging is important to assess possible comminution, and allow a more informed decision regarding the choice of a surgical versus a more conservative approach to treatment of the injury. Reported fractures of the vertical ramus include transverse and oblique configurations, but perhaps the most commonly encountered involve the angle of the mandible. Caudal mandibular fractures can be treated using a conservative approach, or by compression plating or external fixation.

Most fractures of the caudal region of the body or ramus of the mandible, but especially those resulting in minimal instability, malocclusion, and pain, are candidates for conservative management. The overlying, deep and tightly attached pterygoid and masseter muscles confer significant stability to these fractures, acting much in the manner of a splint. Anti-inflammatory medication increases patient comfort, and feeding mashes of complete pelleted feeds provides nutrition in an easily consumed form. Antimicrobial therapy is indicated when the fracture is open to the oral cavity, and oral lavage may be of benefit in such cases. Some horses are inappetent immediately following such injuries and ensuring adequate hydration is imperative in these cases. However, in those animals without major intra-oral fragmentation, it is often surprising how little discomfort they exhibit compared to human patients with similar injuries.

Radiological evaluation of the fracture should be performed periodically. Possible indications for internal fixation of the fracture are lack of healing or osteomyelitis at the fracture site; however, the best guide to progress is the clinical status of the patient. Most fractures of the horizontal ramus involve the alveoli of the adjacent cheek teeth, and the resulting inflammatory response and possible contamination of the site through external or oral wounds may cause pulpitis and loss of vitality of one or more teeth.

Radiological assessment may demonstrate clear evidence of such dental infection; however, it is important to defer any possible dental extraction procedures until such time as the mandibular fracture has stabilized. Exodontia is rarely a surgical imperative and being traumatic in nature demands a stable mandible if further injury to the patient is to be avoided.

Fracture of the caudal angle of the mandible with degloving of the overlying soft tissues has been described.⁸ The injury results from placement of the head between stationary objects and then pulling back; similar injuries can occur following other forms of direct trauma, and may also cause facial nerve damage. Communication of such fractures with the oral cavity or adjacent alveoli is uncommon. Surgical removal of small fracture fragments can be performed with minimal functional or cosmetic disturbance. However, it is usually better practice to let these remain in situ in the hope that they may be incorporated into the fracture healing process, which is usually the case. It is only occasionally necessary to carry out sequestrectomy several weeks post-injury. Although most heal without complication, internal fixation may be indicated for larger fragments, where a ventrolateral approach to the mandible is used. It is critical that the facial artery, facial vein, parotid salivary duct and mental nerve are identified and preserved during surgical dissection. Elevation of the masseter muscle from the mandible is necessary and accomplished by transection of the attachments of the muscle at the ventral border of the mandible and reflecting the muscle dorsally. The orthopedic plate used depends entirely on fracture configuration and size of the patient. The plate should be placed on the ventrolateral aspect of the mandible, if possible. The plate is contoured and attached to the bone; a minimum of three screws on either side of the fracture is recommended. Dental apices should be avoided when applying screws more rostrally in young horses.

A similar approach may be adopted for fractures of the vertical ramus. Although most are treated conservatively, surgical repair may be considered if a fracture is grossly unstable, or if there is marked malocclusion preventing prehension or mastication, pain with unwillingness to eat, or if the fracture is bilateral. Internal or external fixation can be used to stabilize such fractures. However, with the exception of those causing major dysfunction of the temporomandibular joint, the splinting effect of the heavy muscles of mastication is usually effective in preventing major fragment displacement until fracture healing. Although bone plating provides a very stable construct, extensive surgical dissection is required at a site containing many large blood vessels, parotid tissue and the facial nerve. Fractures open to the oral cavity can be expected to become infected, necessitating removal of plates after fracture healing. External fixators can also be used in the treatment of caudal fractures of the mandibular body.

The prognosis for healing of caudal mandibular fractures is guarded to good. Complications are usually associated with communication with the oral cavity and involvement of the teeth. When surgical repair is undertaken, aggressive debridement of the fracture line with thorough lavage, and closure of oral mucous membranes (if possible) are the best means of preventing osteomyelitis and sequestration. Implant-associated infection necessitates removal of plates or pins, debridement of soft tissues, lavage, and antibiotic medication. Resolution of infection after implant removal often proceeds without further complication. Failure of fracture healing is a significant complication. This will depend on the degree of stability and, most importantly, on the presence of infection. Use of a more stable means of fixation and addressing any infection ensure the best prognosis for complete healing. Adjunctive therapy, including autogenous cancellous bone grafting and antimicrobial impregnated beads, may be indicated.

References

1. Szpadarska AM, Zuckerman JD, DiPietro LA. Differential injury responses in oral mucosal and cutaneous wounds. *J Dent Res* 2003; 82(8): 621–626
2. Schrementi ME, Ferreira, AM, Zender C, DiPietro LA. Site-specific production of TGF- β in oral mucosal and cutaneous wounds. *Wound Repair Regen* 2008; 16(1): 80–86
3. Ramzan PH, Marr CM, Meehan J, Thompson A. Novel oblique radiographic projection of the temporomandibular articulation of horses. *Vet Rec* 2008; 162(22): 714–716
4. Nagy AD, Simhofer H. Mandibular condylectomy and meniscectomy for the treatment of septic temporomandibular joint arthritis in a horse. *Vet Surg* 2006; 35(7): 663–668
5. Sullins KE, Turner AS. Management of fractures of the equine mandible and premaxilla (incisive bone). *Compendium Continuing Education for the Practicing Veterinarian* 1982; 4(11): 480–489
6. DeBowes RM. Fractures of the mandible and maxilla. In: Nixon AJ, ed. *Equine fracture repair*. WB Saunders, Philadelphia, 1996, pp 323–332
7. Henninger RW, Beard WL, Schneider RK, et al. Fractures of the rostral portion of the mandible and maxilla in horses: 89 cases (1979–1997). *Journal of the American Veterinary Medical Association* 1999; 214: 1648–1652
8. Knox PM, Crabill MR, Honnas CM. Mandibular and maxillary fracture osteosynthesis. In: Baker GJ, Easley J, eds. *Equine dentistry*. Elsevier, Philadelphia, 2005

Equine dental pathology

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Introduction

Equine dental disorders are of major importance in the UK, with a survey showing that 10% of equine practice time is spent on dental-related work.¹ Likewise, a US survey ranked dental disorders as the third most common equine medical problem encountered by large animal practitioners.² Despite its importance, equine dentistry is a neglected discipline, as exemplified by a survey of 150 adult horses without any history of dental disease which showed 24% of them to have dental abnormalities.³ Numerous post-mortem studies have also indicated up to 80% prevalence of undiagnosed, clinically significant dental disorders in equids.^{4–7} Interestingly, dental disorders, such as cheek teeth (CT) displacements, wear abnormalities, and diastemata, have even been noted in skulls examined from wild equids (Cape Mountain zebras) that died of causes unrelated to dental disease,⁸ and some prehistoric horse skulls in museums also have evidence of similar dental disorders (P.M. Dixon, unpublished observations), highlighting that these abnormalities are not necessarily diseases of domestication.

Most earlier studies of equine dental pathology concentrated on gross findings, with many of them examining skulls with unknown dental histories collected from abattoirs. In one such abattoir study of 365 skulls, Honma et al found that all skulls identified as 12 years of age or older had dental caries.⁴ An abattoir study of 218 skulls by Baker⁹ recorded a prevalence of 60% periodontal disease and 79% infundibular caries in horses aged over 15 years. In a study of 355 abattoir skulls, Wafa found 13% of skulls to have abnormalities of development or eruption; 17% with wear abnormalities; 35% with periodontal disease; 29% with caries and 6.5% with dental pulp exposure.⁶ He concluded this latter disorder was 'of greatest clinical significance' and that all of the periapical infections identified could be attributed to exposure of the dental pulp.

Dixon et al detailed the prevalence of dental disorders in a referred population of 400 dental cases, most being of a severe nature as would be typical of referred cases,^{10–13} including 162 cases which were referred because of what was termed 'primary' (i.e., of unknown etiology) CT apical abscessation.¹⁰ Pulpal exposure was clinically identified in a small number of these 162 cases of CT apical abscessation, in contrast to Wafa's findings.⁶ Many additional CT apical infections were found to have arisen from concurrent dental

disorders, such as deep periodontal pocketing following dental displacement, that were defined as 'secondary' apical infections.^{11–13} Brigham and Duncanson's study of 50 abattoir skulls found most dental disorders to involve CT, including recording that 20% of skulls had CT diastema; 26% had focal CT overgrowths; 56% had sharp enamel overgrowths; 20% had missing teeth; 8% had 'wavemouth' and 12% had CT caries.¹⁴ More recently, a high prevalence of dental disorders, and in particular CT diastemata, was demonstrated in aged donkeys in a post-mortem survey,⁷ and many of these serious dental disorders manifested between 15 and 20 years of age.¹⁵ Horses can suffer a wide range of dental disorders of development and eruption that are covered in Chapter 8, and this review primarily deals with acquired dental disorders.

Abnormalities of wear

Normal tooth wear (attrition) begins when opposing teeth come into occlusion and their occlusal surfaces grind off each other.¹⁶ Any asymmetry in the position of the jaws (as occurs with craniofacial abnormalities) or of individual teeth (e.g., with developmental displacements of teeth) results in uneven dental wear. The periodontal membranes adjacent to overgrown teeth are often diseased, including due to abnormal rostrocaudal drifting of overgrown teeth causing diastemata. Additionally, the pain and possibly mechanical obstruction caused by dental overgrowths can restrict masticatory movements that in turn restrict intra-oral saliva and food movements. Overgrowths can also cause soft tissue trauma, which can lead to clinical signs such as biting abnormalities in ridden horses and less commonly to quidding.

Cheek teeth enamel overgrowths

The presence of anisognathia in equids and the fact that their maxillary CT are wider than their mandibular CT contributes to the development of enamel overgrowths on the buccal aspect of their maxillary CT and lingual aspect of their mandibular CT¹⁷ (Fig. 10.1).

These sharp points may lead to soft tissue ulceration of the buccal mucosa (rarely to tongue ulceration) and in severe cases may cause clinical signs, such as biting problems and even quidding.¹⁷ Recently, the masticatory movements of the

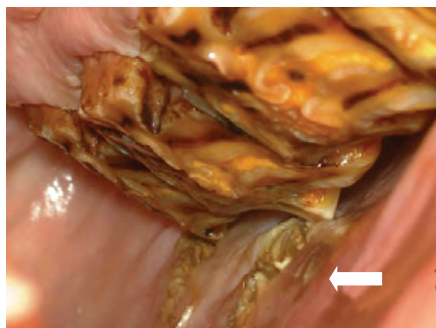


Fig. 10.1 Intra-oral view of buccal ulceration (arrow) caused by prominent vertical ridges on caudal maxillary CT. These CT appear to have minimal occlusal angulation and it is the more lateral prominence of their vertical ridges (cingulae) that is traumatizing the cheeks.

mandible have been examined using a 3-dimensional kinematic model with differences shown in the amplitude of movement between individual horses.¹⁸ The equine chewing cycle has three phases: opening stroke, closing stroke and power stroke, as discussed in detail in Chapter 6. The vertical 'crushing' stroke predominates when high levels of concentrates are fed¹⁹ that, along with the reduced amount of time spent masticating concentrate foodstuffs, promotes the development of CT enamel overgrowths and increased CT occlusal angles. In contrast, horses fed predominantly roughage have a greater degree of lateral excursion during mastication.²⁰ Roughage also requires more chewing movements (3000–3500 per kg consumed) compared with concentrates (800–1200 per kg). The number of chewing movements, per unit of roughage and concentrate, has been shown to be higher in ponies than in larger breeds,^{19,21} possibly due to the smaller size of their teeth.

It is generally believed that equids fed predominantly roughage do not develop cheek teeth enamel overgrowths; for example, earlier studies cited by Becker (1962)²² found no enamel overgrowths in fossilized equine skulls, and Becker found minimal or no enamel overgrowths in wild zebras, wild asses, and Przewalski's horses.²² However, a recent study on working equids that never had any dental treatment showed significant cheek teeth enamel overgrowths to be present in them despite being fed a predominantly roughage based diet.²³ Furthermore, a population of Exmoor ponies that are only fed roughage continue to develop sharp enamel overgrowths that are recognised when they are re-presented annually for routine dental treatments (P.M. Dixon, N du Toit, personal observations). Some domesticated breeds may be genetically predisposed to developing sharp enamel points. For example, it is possible that variations in the width of the normal vertical ridges on the buccal (lateral) aspect of maxillary cheek teeth (cingulae) may be a factor in the development of enamel overgrowths, with horses with wider ridges most likely to develop large enamel overgrowths on the buccal aspect of these ridges that cause clinical signs. Enamel overgrowths predominantly cause clinically significant disease in ridden horses, especially when associated with certain practices, such as the use of tight nosebands.^{23,24}

The occlusal surfaces of equine teeth have linearly shaped groups of cusps (elevations), termed transverse ridges



Fig. 10.2 This right maxillary CT row has markedly increased (circa 45°) occlusal angulation, i.e., shear mouth.

(usually 11–14), on the maxillary and mandibular CT, that interdigitate with the opposing teeth, and their evolution has been described in Chapter 1. These ridges increase the occlusal surface area for grinding coarse fibers and are the result of enamel infoldings causing different occlusal wear patterns. These ridges can be more prominent in young horses, with much individual variation in their height. The presence of multiple tall ridges should not be regarded as an abnormality, despite the dogma of some equine dental groups. Such physiological transverse ridges need to be differentiated from true overgrowth (exaggerated or accentuated) transverse ridges which can, for example, develop opposite a wide diastema or occasionally can develop on individual ridges amongst even-sized ridges, possibly due to reduced enamel content on the opposing tooth.

Shear mouth

If the above generalized CT overgrowths are not managed by routine dental floating, they may increase to such an extent that they interfere with the normal side-to-side masticatory action (and the small degree of mandibular rostro-caudal movement). This further perpetuates the overgrowths and may lead to a condition termed shear mouth.^{13,25} In contrast to former beliefs that CT occlusal angles of >15° could be termed shear mouth, it is now accepted that affected teeth have in fact much steeper angles (>45°) of their occlusal surfaces (Fig. 10.2).²⁶ Horses affected with shear mouth have reduced effectiveness at grinding food, especially dried forage such as hay, and eventually exhibit quidding, due to soft tissue injury and to the inevitable periodontal disease

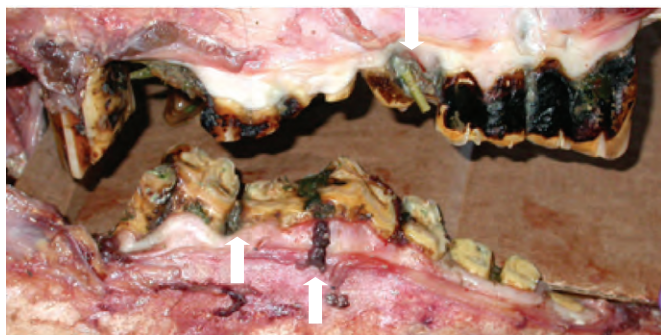


Fig. 10.3 Post-mortem image of a neglected, aged equine mouth that has multiple dental abnormalities, including wave mouth in the centre of the CT rows, smooth mouth of the rostral mandibular CT (406, 407 are worn to their component roots) and step mouth of 111 due to loss of 411. Diastemata and associated periodontal disease are present between some teeth (arrows).

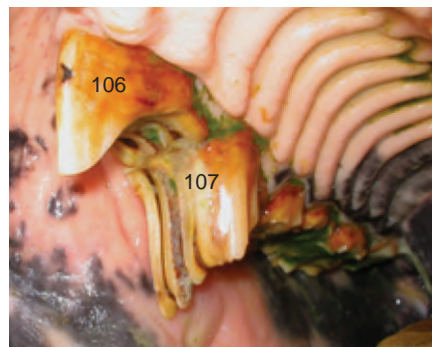


Fig. 10.4 These two major maxillary CT overgrowths have been caused by loss of the opposite 407, with marked caudal drifting of the 406 into the extraction space. This has caused a rostral overgrowth to develop on the partly unopposed 106, and a tall, narrow, triangular overgrowth to develop on the 107.

that accompanies this disorder. Numerous studies have shown the prevalence of shear mouth to be low (0.6–12%),^{3,6,7,13} and this was particularly so in a large study of 30 000 (younger) cavalry horses where a prevalence of only 0.03% was found.²² Two recent donkey studies did not find an increasing prevalence of shear mouth with increasing age,^{7,15} and so it can be concluded that generalized shear mouth is an uncommon disorder of geriatric equids.

Wave mouth

Wave mouth is the presence of an undulating occlusal surface of the CT arcade in a rostrocaudal direction (Fig. 10.3). This disorder has been hypothesized to occur in some CT secondary to marked periodontal disease, which disrupts the normal eruption process.¹³ Differential rate of CT eruption between different CT in a row has also been proposed as a cause of wave mouth (that may even increase with time),^{22,27} as has the presence of large focal overgrowths²⁸ (e.g., due to absent or defective opposing teeth) and diastemata,^{15,29} but it is most likely that the etiology of wave mouth is multifactorial. Severe wave mouth can cause restricted mastication, and concurrent dental (e.g., shear mouth or diastemata) and periodontal disorders are inevitably present. The prevalence of wave mouth has been shown to be relatively low (2–19%) in most equine surveys,^{3,6,7} and (in contrast to shear mouth) wave mouth was significantly associated with age in two donkey studies.^{29,30}

Step mouth

Classically, the loss of a cheek tooth is alleged to cause a rectangular shaped overgrowth due to 'super-eruption' of the unopposed opposite CT, leading to a condition termed step mouth (Fig. 10.3). Dixon et al¹³ found that 40% of cases of step mouth were caused by CT maleruptions, such as different rates of eruption of opposing CT, with the earlier erupted CT becoming and remaining overgrown ('dominant').^{17,22} As noted above, less severe cases of CT maleruption may lead to wave mouth and there is often an overlap between these two disorders. Overgrown teeth may be rectangular in shape, especially in the early stages following loss of an opposite tooth, but as the teeth on either side of the

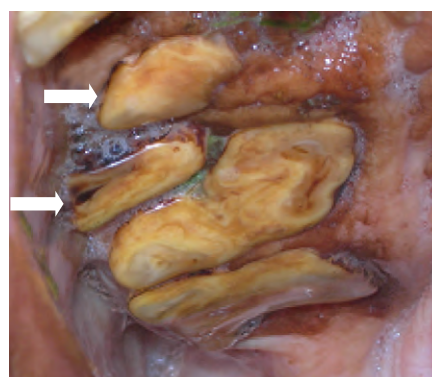


Fig. 10.5 These caudal maxillary CT (109–111) have minimal enamel (focal white areas) remaining and thus have a smooth occlusal surface. Additionally, the more rostral CT in the image (109) is worn down to its component roots (arrows).

missing tooth (variably) drift together, a triangular-shaped overgrowth can develop (Fig. 10.4).³¹ These overgrowths can mechanically interfere with normal mastication, leading to wave mouth or shear mouth. They may also cause oral pain that may be manifested as oral pain with quidding, halitosis, and weight loss.²⁸

The maxillary CT of older horses with worn infundibula, or maxillary CT with developmentally short infundibula or infundibular caries, have reduced enamel content that allows the opposite mandibular CT to focally overgrow. Similarly, older horses or horses with reduced peripheral enamel infolding of their mandibular CT develop overgrowths of the opposite maxillary CT. A clinical survey of donkeys showed step mouth to be significantly associated with the presence of missing, overgrown and worn CT, and CT diastemata.³⁰ The prevalence of step mouth varied from 3.7 to 12% in different equid studies^{3,6,7,13} and is significantly associated with increasing age in donkeys.^{29,30}

Smooth mouth

In older equids, the loss or reduction of enamel ridges is a normal physiological end-stage phenomenon of dental attrition³² (Fig. 10.5). This leads to the development of a smooth occlusal surface containing predominantly cementum and

dentin, with minimal protruding enamel that is termed smooth mouth. Such dentin and cementum are no longer protected from increased wear by harder enamel, and such teeth are ineffective at grinding, becoming more rapidly worn.³³ Older equid teeth commonly develop hypercementosis of the apical area, which will increase once the roots become exposed, which is a protective mechanism to prolong the dental lifespan of geriatric equids.^{32,33} As expected, smooth mouth is significantly associated with increasing age in donkeys.^{29,30} The prevalence of smooth mouth has been shown to be quite low (up to 5%) in some general surveys, with an increased prevalence (20–35%) in equids over 20 years of age.^{6,7,15} Occasionally smooth mouth can develop in younger equids where, as noted above, there is insufficient enamel infolding of peripheral enamel, absence of maxillary CT infundibula²⁸ or the presence of enamel dysplasia (see Chapter 8).

Diastemata

All 6 CT in each row should act as a single functional unit and should be tightly opposed to each other at the occlusal surface due to the rostrocaudal angulation of the rostral and caudal CT. Cheek teeth diastema, which is defined as a detectable interdental (interproximal) space between adjacent teeth, was diagnosed as the primary dental disorder in 4% of 400 horses referred for dental disorders by Dixon et al¹² and in 3.6% of horses in an abattoir survey by Wafa.⁶ The caudal mandibular CT were more commonly involved, particularly the interdental (interproximal) spaces between 09s–10s and 10s–11s.^{12,34–36} As noted in Chapter 8, diastemata can be termed *primary* (developmental), which develop due to inadequate rostrocaudal CT angulation or due to embryonic buds developing too far apart.^{34,35,37} In contrast, if the supporting bones are not large enough to support the developing dental buds, overcrowding of erupted teeth results in displacement of these CT with subsequent *secondary* developmental diastemata developing.³⁵

Equine CT taper towards their apices, and the angulated equine CT (6s, 10s and 11s) lose their angulation with age. Therefore, with continued dental eruption, *senile* diastemata commonly develop between the CT in aged horses.³⁶ Diastemata can also develop secondary to loss of CT or adjacent to acquired CT displacements, more commonly seen as lingual (medial) displacement of the mandibular 10s and 11s.^{34,35} Interestingly, diastemata have also been identified in a survey of free-ranging Cape Mountain Zebras (*Equus zebra zebra*).⁸

Diastemata have also been classified as closed/valve diastemata (narrower occlusally; Fig. 10.6) or open (same width at occlusal and gingival margin) diastemata (Fig. 10.7).³⁸ Sharp overgrowths or exaggerated transverse ridges on opposite CT may widen diastemata and compress food into them;^{12,28} however, the most clinically significant valve diastemata have a narrow (1–3 mm) space between the teeth occlusally (Figs 10.6, 10.8–10.10), with no detectable overgrowth on the opposite tooth. The presence of diastemata usually leads to compression of food into the abnormal space between the two adjacent teeth, with resultant periodontal food pocketing (especially into valve diastemata) and periodontal disease,^{6,36} as previously illustrated in Chapter 8.



Fig. 10.6 This post-mortem image of a caudal right hemimandible has two valve diastemata (narrow occlusally and wider at gingival level) with deep periodontal food pocketing between the two CT on the right.



Fig. 10.7 These mandibular CT (306–307) have an open diastema between them, but due to the shape of the diastema, it contains no food pocketing. Consequently, the underlying gingiva, although recessed, has a smooth appearance and is of normal color.

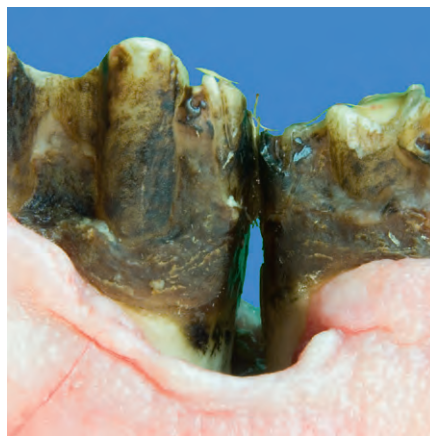


Fig. 10.8 These two mandibular CT have a valve diastema between them that has led to marked periodontal recession at, and adjacent to, the diastema. These two CT also have loss of much of their peripheral cementum likely due to prior peripheral dental caries, with marked staining of all exposed calcified tissues. (Courtesy of Alistair Cox and Sionagh Smith.)

With marked food entrapment, the periodontal disease progresses to cause lysis and remodeling of alveolar bone and even osteomyelitis of the mandible or maxillae¹⁷ or oromaxillary fistula formation. The most common clinical sign seen with CT diastemata is quidding and so periodontal disease is regarded as one of the most painful dental disorders of horses.^{12,28,34} Open mouth radiography (Fig. 10.10) is of great value in assessing the cause, severity and prognosis with CT diastemata.³⁹ In younger horses with this disorder, further eruption of the CT and compression of the CT rows may even result in resolution of the diastemata, provided there is sufficient CT angulation.

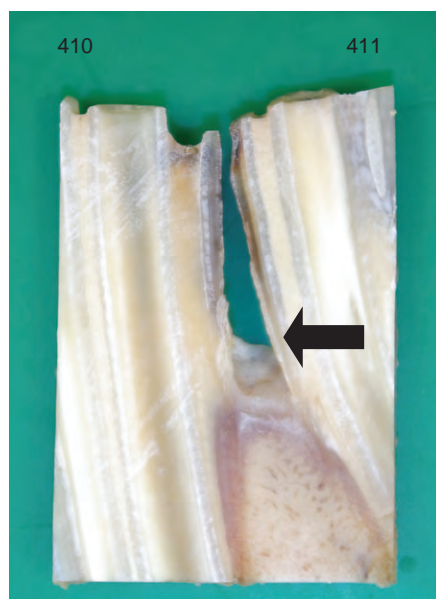


Fig. 10.9 A longitudinal section from an undecalcified hemimandible showing two adjacent CT (410, 411) that have a valve diastema between them. There is recession of the gingiva overlying the mandibular bone beneath the diastema, with pocket formation (arrow). (Courtesy of Alistair Cox and Sionagh Smith.)

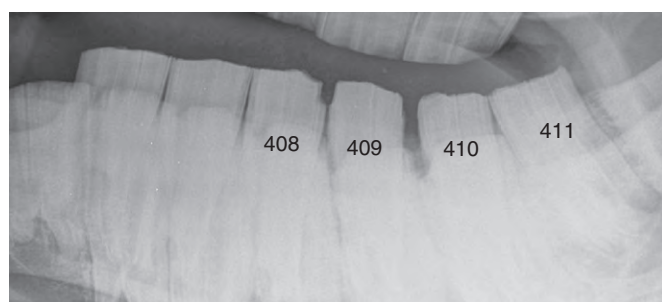


Fig. 10.10 Open mouth radiograph of a right hemimandible showing a valve diastema between 408–409 (that has been mechanically widened) and an open diastema between 409 and 410. There is adequate angulation of the caudal CT in this horse, but the CT have developed too far apart in this hemimandible.

Periodontal disease

Periodontal disease (periodontitis, paradontal disease, alveolar disease and alveolar periostitis) describes inflammation of the supporting structures of the tooth, i.e., the gingiva, periodontal ligaments, cementum, and alveolar bone.^{6,40,41} In addition to its enormous importance in human dentistry, periodontitis has been recorded as an important disease in dogs and cats,⁴² sheep^{43,44} and cattle.⁴⁵ Colyer described periodontitis as a most significant equine dental disease ('the scourge of the horse') with a prevalence of 33 % recorded in an abattoir survey of 484 horses.⁴⁰ However, examination of photographs of Colyer's specimens⁴⁰ shows that the periodontitis was predominantly secondary to other disorders, such as diastemata and displaced teeth.¹² Other early studies have also reported the presence of periodontal disease in

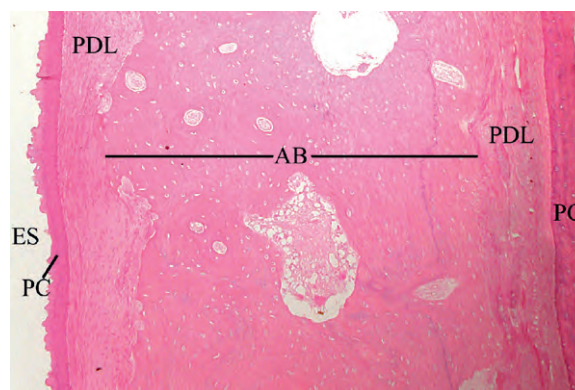


Fig. 10.11 Decalcified longitudinal section of an equine mandible showing the normal subgingival structures between the two adjacent cheek teeth, including the very vascular alveolar bone (AB), with its irregular margins on both sides attached to the periodontal ligaments (PDL). The peripheral cementum (PC) has a smooth margin with the periodontal ligament, but a scalloped margin with the adjacent enamel (ES – enamel site – as enamel is fully removed during decalcification). (Original magnification $\times 100$.) (Courtesy of Alistair Cox and Sionagh Smith.)

horses,^{41,46} and periodontal disease secondary to diastemata has also been described in zebras.⁸

More recent studies of horses have also recognized periodontitis as a significant disorder.^{6,9,12,13,47} Baker (1970) and Wafa (1988) found that 60 % of horses over 15 and 20 years of age, respectively, suffered from periodontal disease.^{6,9} However, most often this periodontal disease was secondary to other disorders such as displaced teeth or CT diastema. More recent clinical studies have also shown virtually all equine periodontal disease to be associated with abnormal interdental spaces, such as between CT diastemata.^{12,13} Periodontal disease in donkeys is also significantly associated with diastemata, overgrown teeth, displaced teeth, and increasing age.³⁰ Both Baker and Wafa also recognized a mild transient periodontitis associated with CT eruption, with a prevalence of 40 and 52 % respectively, in immature skulls.^{6,9} Little pathological research has been performed on equine periodontal disease, and it is likely that these constantly remodeling tissues (in a hypsodont species) differ from those in brachyodont species. A histological image of normal equine periodontal and adjacent tissues is shown in Figure 10.11.

Periodontitis in brachyodont species is initiated by the adherence of organic dental plaque and bacteria to teeth.⁴² Later, the plaque may become calcified to form dental calculus that consists of 70–90 % minerals. A similar finding in equine teeth is illustrated in Figure 10.12. The main component of equine dental calculus is calcite, which has a chalky appearance. In horses, dental calculus most commonly occurs on the lower canine teeth and less commonly on the buccal aspects of the rostral maxillary CT (excluding the wolf tooth),¹⁶ and the associated, usually low-grade, periodontal disease usually resolves following removal of the calculus. In general, dental calculus is not a significant problem of equine CT that do not have intercurrent dental disorders.^{6,9,13} This low prevalence of calculus on equine CT may be due to the prolonged time horses spend masticating, as the prolonged intra-oral movement of fibrous food and saliva during mastication may deter the formation of plaque,⁴² although equine teeth are covered with an organic pellicle.

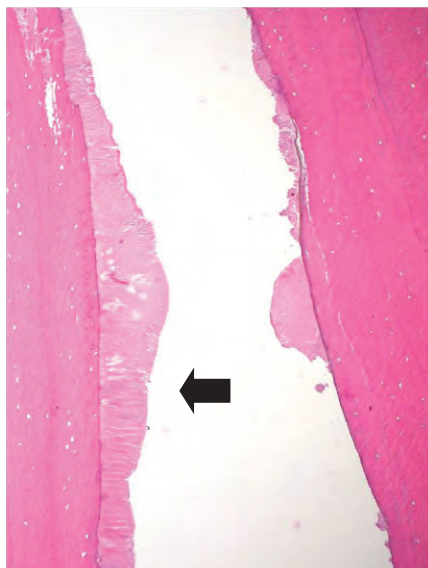


Fig. 10.12 Decalcified histological section of a CT diastema showing organic plaque deposition (arrow) on the peripheral cementum on both sides of the diastema. (Original magnification $\times 100$). (Courtesy of Alistair Cox and Sionagh Smith.)

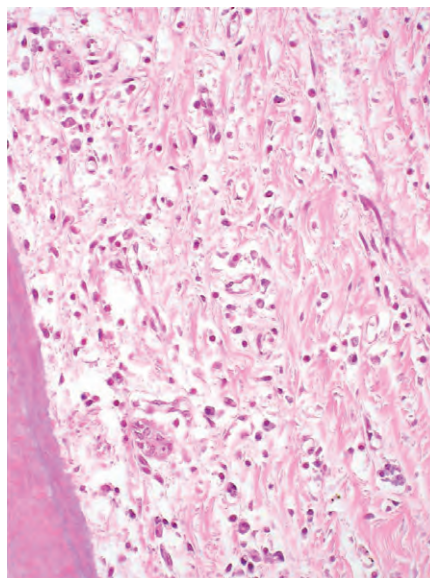


Fig. 10.14 Decalcified histological section of subgingival connective tissue in the interproximal space of a CT diastema showing moderate infiltration with mononuclear inflammatory cells. (Original magnification $\times 200$). (Courtesy of Alistair Cox and Sionagh Smith.)

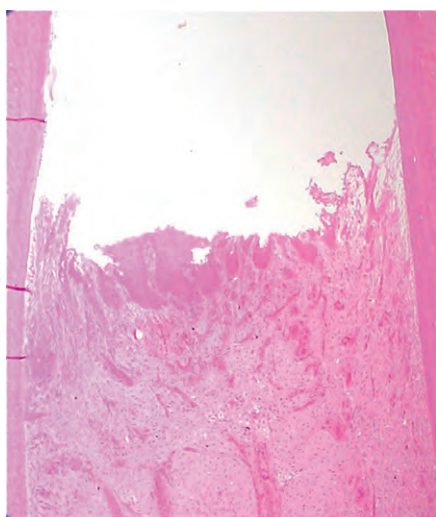


Fig. 10.13 Decalcified histological image of the base of a valve CT diastema showing erosion and hyperplasia of the gingiva in the interproximal space. (Original magnification $\times 100$). (Courtesy of Alistair Cox and Sionagh Smith.)

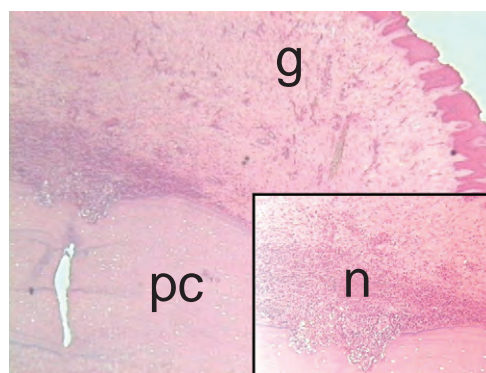


Fig. 10.15 Localized periodontitis where a neutrophilic infiltration (n: inset lower right) is present within the gingiva (g), and the peripheral cementum (pc) has already receded through carious attack (H and E).

In brachydont teeth, periodontal disease starts with loss of the normal tight gingival attachment between adjacent teeth. This gingiva then becomes inflamed due to mechanical irritation, e.g., to impacted food particles and from chemical irritation from bacteria, food, and plaque. As the gingival destruction continues, the gingival defect becomes further impacted with food, and the process perpetuates itself with the periodontitis extending deeper into the periodontal ligament and also to the buccal and lingual margins of teeth, forming large periodontal food pockets¹⁶ (Figs 10.13–10.15). This inflammation and infection may even extend to the alveolar bone, and even supporting bones, causing alveolar bone remodeling and even bone

necrosis and infection. Eventually the tooth becomes loose and may even spontaneously be shed due to loss of supporting structures.⁴⁰ More localized extension of the periodontal disease can lead to infection of the pulp, apical infection, and ultimately death of the tooth.^{42,46} A periodontal disease grading system (0–4) used in small animals that is based on the percentage of dental attachment loss⁴² could be used in equids (Table 10.1).

Disorders of pulp

Pulpitis

Pulpitis or inflammation of the pulp in human teeth occurs most commonly secondary to dental caries that has penetrated the enamel and dentin,⁴⁸ and is usually associated with pain (often a dull, throbbing pain synchronous with the heartbeat as blood pressure increases in the inflamed but

Table 10.1 Equine periodontal disease grading system

Stage 0	Normal
Stage 1	Gingivitis
Stage 2	Early periodontal disease (up to 25% attachment loss)
Stage 3	Moderate (25–50% attachment loss)
Stage 4	Severe (greater than 50% attachment loss)

confined pulp, in contrast to the sharp sudden pain of dentin exposure). Other potential causes of pulpitis in all species include bacterial penetration via pulp exposure secondary to attrition, abrasion, or trauma; chemical irritation (e.g., from irritant molecules directly applied to pulp or by their diffusion through adjacent dentin after insertion of restorative material); thermal damage i.e., heat produced from motorized dental equipment; or iatrogenic pulpar exposure. Because of the intimate relationship between dentin and pulp, together they have been termed the dentinopulp complex, which emphasizes the fact that an insult to dentin can also insult pulp.

The inflammatory response by pulp includes the development of edema and the influx of lymphocytes, plasma cells, and macrophages. Due to pulp being completely encased in its rigid dentinal chamber, the inflammatory response increases the pressure in the pulp chamber/horn that can cause a collapse of the venous microcirculation. This can result in areas of pulpar hypoxia and anoxia that may lead to localized or generalized pulp necrosis and death. However, equine CT, especially when young, have large apical foramina and a large blood supply to their pulp and so can often survive a degree of pulpar edema and inflammation that would cause pulpar death in brachydont teeth. If the pulp survives, it allows tertiary dentin formation to seal off the area of insulted (e.g., exposed) pulp, and this hopefully results in complete resolution of the pulpitis.⁴⁹

Pulp stones

Pulp stones, more correctly termed false pulp stones because they are composed of concentric layers of calcified tissue *without* any internal tubular structure, have been observed in equine teeth, both within viable pulp (free stones) and in areas replaced with secondary dentin (Fig. 10.16). A study that examined just four transverse histological sections per equine CT found false pulp stones present in 5/51 normal maxillary and 1/49 normal mandibular CT,⁴⁹ but it is obvious that they have a much higher prevalence in healthy equine CT. Their presence in brachydont teeth is often stated to be evidence of pulpar irritation or inflammation that could arise from focal areas of anachoretic pulpitis, or from other noxious stimuli including chemical, bacterial, vibrational (mechanical) or thermal stimuli.⁵⁰ The formation of pulp stones creates a corresponding decrease in the functional size of the pulp chamber that may compromise pulpar microcirculation and in turn may affect the rate of dentin production. However, their frequent occurrence in grossly normal equine CT as indicated above shows that many equine CT contain (false) pulp stones that do not compromise their pulp vitality.⁴⁹

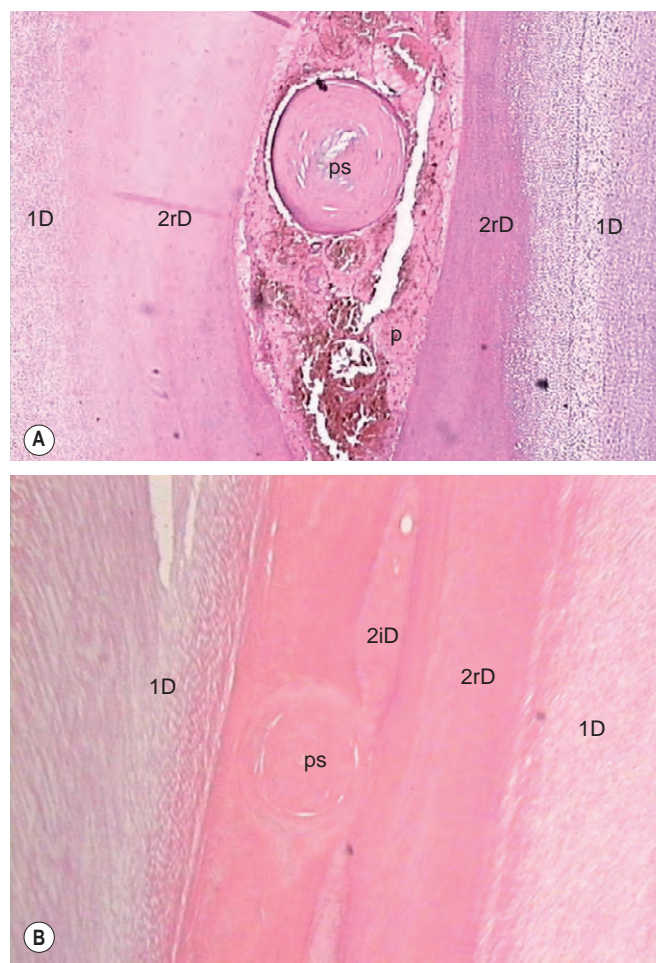


Fig. 10.16 (A) A single pulp stone (ps) has formed in the middle of this partially autolyzed dental pulp. As it remains entirely within the pulp it is termed a 'free' pulp stone (denticle). Regular secondary (2rD) and primary (1D) dentin are present surrounding the pulp (H and E). (B) This pulp stone (ps) has become surrounded by regular (2rD) and irregular (2iD) dentin. The sigmoid curvature of dentinal tubules (as they head from the pulp to the amelodentinal junction) is partially visible in the primary dentin (1D) (H and E).

Occlusal pulpar exposure

Odontoblasts that line the pulp cavity produce secondary dentin that gradually obliterates the pulp cavity circumferentially and subocclusally over the life of the tooth.⁵⁰ In particular, subocclusal secondary deposition prevents pulp horns from becoming exposed on the occlusal surface in hypsodont teeth with prolonged eruption.^{49,51} Whilst much of this secondary deposition occurs in a time-dependent manner, its deposition is increased by occlusal stimulation, such as by mastication, and in hypsodont teeth (that have exposed odontoblast processes on the occlusal surface), this stimulation is likely to be of more importance in dentinal deposition, than is the case in brachydont teeth. It was previously believed that an imbalance between CT occlusal wear and secondary dentin deposition sub-occlusally could result in exposure of the pulp horns on the occlusal surface, resulting in food becoming impacted within the exposed pulp horns, descending infection and ultimately apical infection of the CT.^{6,37,52} However, recent studies^{53–56} have indicated that occlusal pulpar exposure does *not* occur in healthy

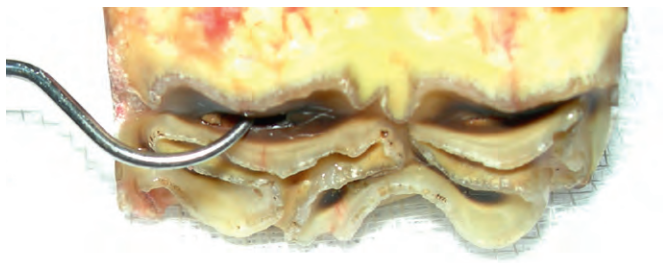


Fig. 10.17 This mandibular CT, which was extracted because of apical infection, has pulpar exposure of the two lateral pulp horns, and a probe has been inserted through the defective secondary dentin into one pulp horn.

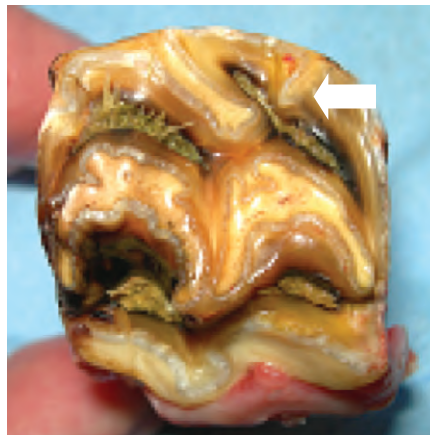


Fig. 10.18 This maxillary CT has occlusal pulpar exposure of all 5 pulp horns (food is protruding from all) with coalescence of the 3rd and 5th pulp horns (arrow).

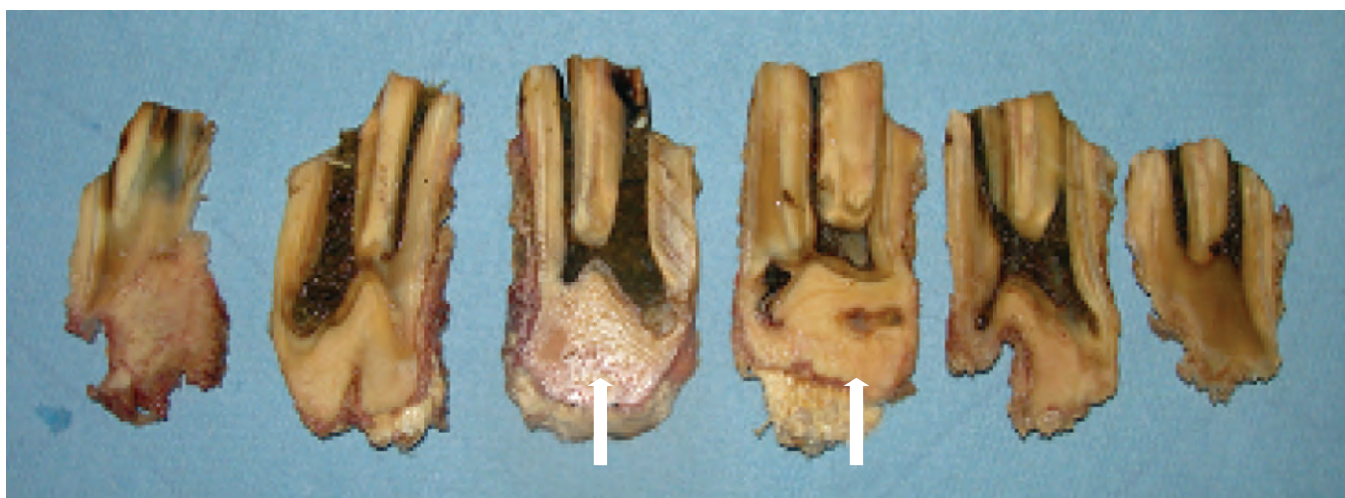


Fig. 10.19 This aged CT (extracted at post-mortem examination) has multiple occlusal pulpar exposure with all pulp horns filled with food material. Extensive periapical cemental deposition (arrows) has sealed off all the pulp horns (and the common pulp chamber) from the apex and consequently, no apical infection is present.

equine CT, but is associated with prior pulpar damage that caused cessation or reduced deposition of sub-occlusal secondary dentin that with continued occlusal wear and tooth eruption, leads to occlusal pulpar exposure (Fig. 10.17).

Cheek pulpar exposure can be recognized clinically¹⁰ (Fig. 10.17) and at post-mortem examination⁶ (Figs 10.18–10.20). More recently, computed axial tomography has been shown to be an effective imaging modality to identify occlusal pulpar exposure and/or apical infections of cheek teeth at post mortem and in clinical cases,^{7,57} as shown in the computerized tomography images of these disorders in Chapter 13. Dacre et al^{54,55} found occlusal pulpar exposure in 34% of 41 apically infected mandibular CT (of multiple pulps in 22% of these 41 teeth) and in 23% in 57 apically infected maxillary CT (multiple pulps in 16% of these 57 teeth). van den Enden et al⁵⁶ found occlusal pulpar exposure in 32% of 79 cheek teeth with apical infections (multiple pulpar exposure in 27% and a single pulpar exposure in 5% of teeth). These latter authors also found that 42% of 31 CT with idiopathic fractures had occlusal pulpar exposure (26% of multiple pulps; 16% single pulpar exposure).⁵⁶ Ultrastructural examinations of equine teeth have shown that dentinal tubules are often



Fig. 10.20 These aged maxillary 106 and 107 have occlusal exposure of multiple pulps. There was no evidence of apical infection in either, indicating that the occlusally exposed areas of the pulps were sealed off from their more apical aspects by tertiary dentin.

exposed on the occlusal surface that may provide a potential route of infection of the pulp from the occlusal surface.⁵⁸ Decalcified histological sections of occlusally exposed pulp demonstrated the absence of occlusal secondary dentin, as well as the presence of necrotic pulp and, in some cases, plant material, within the pulp horns^{54,55,59} (Fig. 10.21).

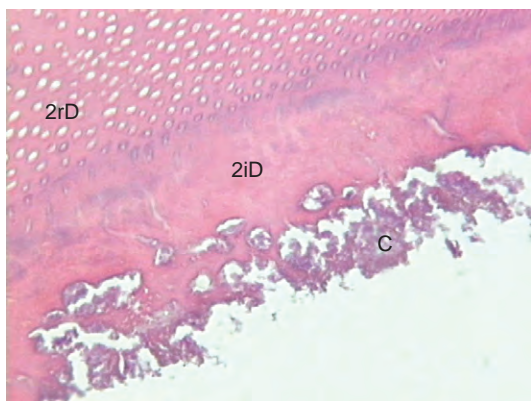


Fig. 10.21 A decalcified transverse histological section of a CT following pulpar exposure, when food and bacteria invaded, destroying any remaining pulp before progressing to attack secondary irregular dentin (2iD) at the carious pulp margin (C). Secondary regular dentin (2rD) is often attacked subsequently (H and E).

Occlusal pulpar exposure less commonly occurs in equid teeth (mainly in older horses) that have no evidence of apical infection,^{55,59} and thus the presence of pulpar exposure does not necessarily indicate that pulpar or tooth death is present (Fig. 10.19). Histological examination of some equid CT with pulpar exposure has shown a layer of tertiary dentin protecting the pulp and sealing it off from an area of insulted pulp at the pulp horn tip that allowed (limited) pulpar exposure.^{55,59} van den Enden et al found occlusal pitting of secondary dentin overlying pulp horns in apically infected cheek teeth; however, in 10% of teeth with apical infections, this pitting did not extend through the full thickness of the secondary dentin to involve the pulp horns.⁵⁶ However, the presence of *multiple* pulp horn exposure, pulpar exposure with marked dentinal caries around the area of pulpar exposure, or of pulps that on probing are found to be deeply (>2 cm) exposed, indicates the likelihood that the entire endodontic system has been severely damaged or is dead. These occlusal findings are likely to be accompanied by clinical signs and/or diagnostic imaging changes indicative of apical infection and dental death.

In cases of acute pulpar exposure (e.g., gross or fissure dental fractures, iatrogenic exposure during dental treatment), the application of calcium hydroxide as a 'pulp-cap' results in the rapid formation of a necrotic zone adjacent to the calcium hydroxide that has a pH of 11 and so has bactericidal actions. A basophilic zone consisting of calcium proteinates forms below this necrotic zone. An adjacent fibrous layer and odontoblast cell layer forms within 2 weeks, followed by a layer of early tertiary dentin 2 weeks later.⁴⁸ The exact mechanism by which calcium hydroxide induces this reparative dentin is unknown. The clinical aspects of this treatment are discussed in Chapter 22.

Apical infections

Apical infection is a more accurate term to use in equids than 'tooth root infection' as such infections commonly occur in young horses prior to any root development, in addition to also occurring in older CT with well developed roots. Incisor or canine apical infections are rare in equids, but CT apical

infections are relatively common, and were the most common reason for dental referral in one study.¹⁰ Apical infection of CT is a particularly important disease of horses because of the length of equine teeth, and consequently the apical infections usually extend to involve the supporting structures, including the periodontal ligament, alveolar and, depending on the site of affected tooth, supporting bones and paranasal sinuses.^{10,37,40} The clinical signs caused by CT apical infections depend on the tooth involved, and the duration and the extent of the infection. A study by Dixon et al of 400 referred horses with dental disease included 41% presented for primary (of unknown etiology) apical infections, including 92 maxillary CT and 70 mandibular CT.¹⁰ When the rostral 2–3 maxillary CT are infected, maxillary swellings and sinus tracts occur, with nasal discharge less common (due to the apical abscess draining medially into the nasal cavity). Sinusitis is almost inevitable if the caudal three maxillary CT are infected. Mandibular swellings and sinus tracts commonly occur with mandibular CT infections.¹⁰

Apical infections occur most commonly in younger horses, and Dixon et al showed that the median age for horses with apical infections of maxillary and mandibular CT was 7 and 5 years, respectively.¹⁰ A further study showed the *dental age* (time since eruption of tooth) of 22 mandibular and 28 maxillary CT with apical infections to be 3.5 years in both groups.^{54,55}

As noted earlier, recent studies have shown that occlusal pulpar exposure of CT is almost certainly a *sequel* to pulpar damage, most usually caused by apical infection, being present in 32% of 79 cheek teeth with apical infections⁵⁶ and in 34% and 23% of 41 and 57 apically infected mandibular and maxillary CT, respectively.^{54,55} Cheek teeth with apical infection have greatly decreased thickness of secondary dentin over all aspects of their pulp canals indicating that chronic pulpar dysfunction or pulpar death was present in many of these CT,⁵³ and that the reduced dentinal thickness was a non-specific finding associated with apical infections of multiple etiologies (Figs 10.22 & 10.23). A commonly recognized cause of equine CT apical infection was anachoretic infection, i.e., blood or lymphatic-borne bacterial infection.^{10,54–56,60} A diagnosis of anachoresis was reached following detailed examination of CT with apical infections that found no other physical route of infection to the apex (Fig. 10.24). Anachoresis was the most common cause of maxillary CT (51% of 57 apical infections) and mandibular CT (59% of 41 apical infections) apical infections in one study.^{54,55} Vertical impactions and hyperemia of the apex due to large eruption cysts ('3- and 4-year-old bumps') may predispose to anachoretic infections,³⁷ and this theory is supported by the higher prevalence of CT apical infections in younger horses. Furthermore, there are anastomoses between the periodontal vasculature and the maxillary sinus blood vessels,⁶¹ possibly allowing bacteria from the upper respiratory tract to be a possible source of CT apical infection, and the converse, as previously noted, with apical infections causing sinus empyema.

Apical infections can also occur secondary to developmental disorders (polyodontia, dental dysplasia, hypoplasia, diastemata, and displacements), usually by an extension of deep descending periodontal disease (because these teeth do not have tight interproximal spaces); wear disorders with associated periodontal disease; or fractures (idiopathic gross or fissure fractures, as well as traumatic fractures).

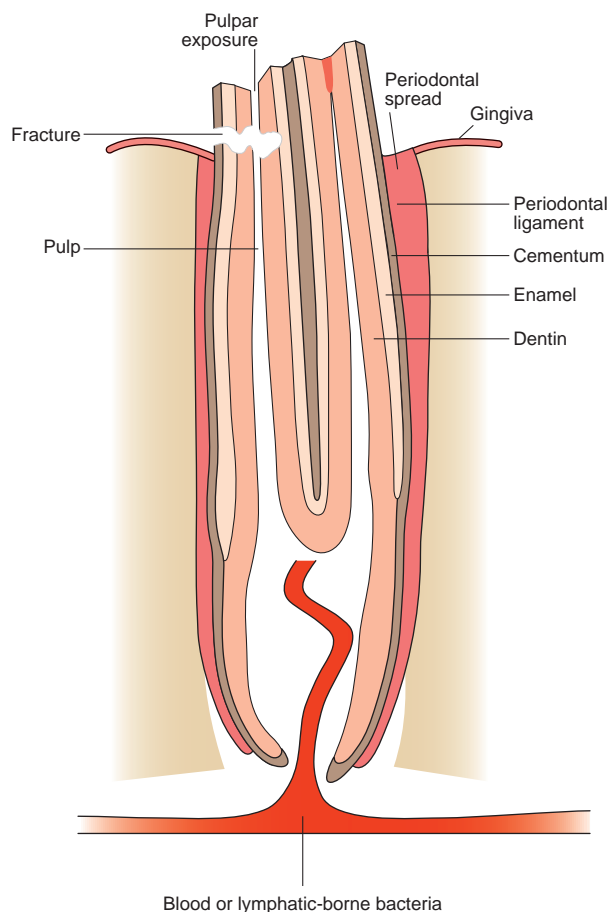


Fig. 10.22 Proposed routes of apical infection in equine mandibular cheek teeth. (Reproduced from Dacre et al,⁵⁴ with permission from The Veterinary Journal.)

A study of 41 apically infected mandibular CT found dental fractures to be the second most common cause (20%) of infection, and included 2 CT with sagittal fractures and 6 with hairline (fissure) fractures communicating between the infected pulp and periphery of the tooth⁵⁴ (Fig. 10.25). The fissure fractures often had dark (bacterial or food pigments) staining on cut sections of affected teeth, but these fissures were usually not very obvious on the surface of the tooth and were never diagnosed clinically. Increased awareness of their significance and more careful examinations of suspect teeth using a dental mirror or intra-oral endoscope should allow their detection.^{62,63} Not all idiopathic fractures (e.g., lateral slab fractures through the lateral pulp horns) result in apical infections, as some such pulps can manage to seal off the exposed pulp by laying down a layer of tertiary dentin to prevent infection spreading down the pulp horn,⁵⁹ as described later. Fissure fractures, were also found to cause apical infections in 9% of infected maxillary CT.⁵⁵

Extension of infundibular caries is a maxillary CT specific disorder that can also cause apical infections. Infundibular cemental hypoplasia with subsequent food impaction in the cemental defect predisposes to the development of infundibular cemental caries that may cause apical infections, either by weakening the tooth structure resulting in midline sagittal fractures or by extension of the caries through the infundibular enamel into dentin and pulp, or occasionally directly

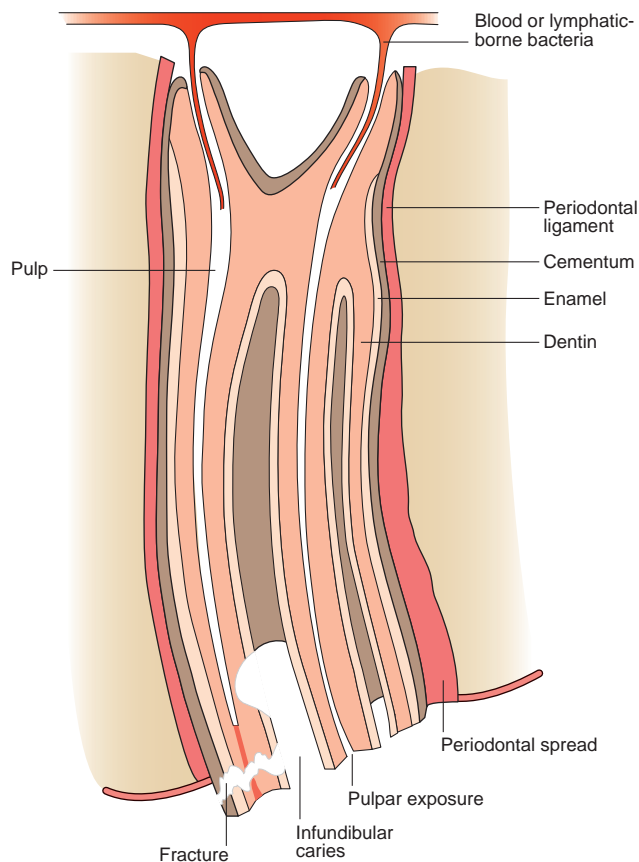


Fig. 10.23 Proposed routes of apical infection in equine maxillary cheek teeth. (Reproduced from Dacre et al⁵⁵ with permission from The Veterinary Journal.)

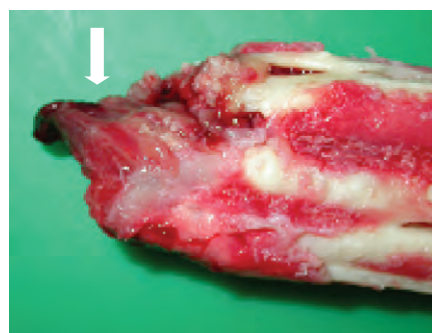


Fig. 10.24 Apex of a mandibular cheek tooth (orally) extracted because of apical infection, showing a chronic proliferative reaction of the periapical tissues (arrow) and slight irregularity on the exposed cementum, but with little evidence of the destructive changes that occur in some apically infected teeth. As no physical route of infection from the oral cavity to the apex was present in this tooth, anachoresis was the likely cause of the apical infection (x2).

onto the apex.^{10,37} Dacre et al found some degree of infundibular cemental caries present in most apically infected maxillary CT examined (Fig. 10.26); however, only 16% of maxillary CT had gross pathological or histological evidence of spread of infundibular caries to involve the pulp or, in one case, directly to the apex.⁵⁵

Periodontal spread is an important route of apical infections in both maxillary CT (12%) and mandibular CT (10%).^{54,55} A periodontal route of apical infection was recognized in the above studies when periodontal disease was found in conjunction with peripheral cemental changes (including dark staining of the residual cementum or exposed enamel) and the loss of *continuous* vertical areas of the periodontal ligament from the apex to the gingival margin.^{54,55} Periodontal disease was deemed to be *secondary* to apical infections in some CT, including the inevitable local areas of periodontitis around the infected apical area, or locally at the gingival margin due to food impaction unrelated to the apical infection.⁵⁴ More chronic cases of secondary periodontal disease that had continuous periodontal tracts from the apex to the gingival margin were believed to be caused by secondary changes, due to drainage of exudate from the apical infection to the gingival margin. Some of these teeth had areas of cemental hyperplasia on their apices and reserve crowns, in contrast to the usual loss of cementum in teeth with descending periodontal infection.⁵⁴

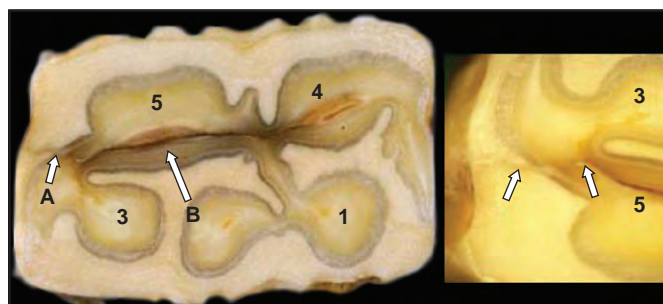


Fig. 10.25 The reverse (apical) face of the occlusal section of an infected 309, dental age 5 years. All five pulp chambers are occluded with secondary dentin; however, pulp chamber 5 is darkly stained around a central fissure (B). A hairline fracture (A) extends through the cementum and enamel at the caudal aspect of the tooth, to join up with the fissure present in the secondary dentin around pulp chamber 5. An enlargement of this area is shown in the insert on right, with arrows identifying the hairline fracture. This infection was acute as evidenced by the presence of normal thickness of dentin and of pulp remnants in all pulp horns more apically. It is possible that if this tooth was not extracted it would have developed a sagittal 'idiopathic' fracture through the 4th and 5th pulp chambers. Note that a newer pulp identification system is now in use – see Chapter 5.

Certain types of dental dysplasia (covered in detail in Chapter 8) are characterized by the presence of dysplastic enamel and hence of abnormalities of dentin and cementum, and such defects were found to predispose to apical infections in 2% and 5% respectively, of mandibular and maxillary CT.^{54,55} Dental dysplasia usually resulted in apical infections via descending periodontal disease, because the abnormally shaped teeth did not fit snugly into the alveoli.⁵⁵ Occlusal and peripheral caries were believed to cause apical infections in just 2% of mandibular and maxillary CT.^{54,55} As commonly occurs in brachydont teeth, it is believed that penetration of bacteria from deep caries down dentinal tubules as demonstrated histologically^{55,56} may result in pulpar and thus apical infection of the tooth (Figs 10.27 & 10.28).

A local response in infected pulp horns is to lay down tertiary dentin to seal off the more apically situated pulp from the exposed or insulted area (Fig. 10.29). However, with death of pulp, such a response is not possible (Fig. 10.30).

Dental caries

Caries is characterized by destruction of the calcified dental tissue with bacteria as the primary initiator of a chain of events. Bacterial fermentation of carbohydrate releases acids that decalcify the inorganic dental components (mainly calcium hydroxyapatite) at pH 4–5.¹⁶ (Fig. 10.31). In brachydont teeth (which have a complete enamel covering), dentin is demineralized very rapidly once the caries has penetrated fully through the enamel and the amelodentinal junction is reached, and the discolored, carious dentin results in the classic black appearance of caries.⁶⁴

The most common type of dental caries identified in equine teeth is maxillary CT infundibular cemental caries.^{10,11,14,65,66} Colyer⁶⁶ observed a prevalence of 13% of infundibular caries, and Honma et al⁴ reported a prevalence of 100% in (maxillary) CT of horses over 12 years of age (Figs 10.32 & 10.33). The maxillary CT of older horses are predisposed to developing caries due to presence of developmental cemental hypoplasia of the infundibula, often at deeper levels, including towards the apical aspect of the infundibulum, that only becomes occlusally exposed with

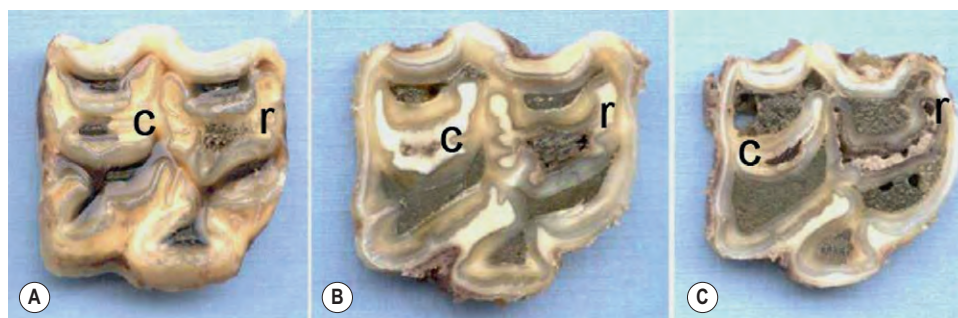


Fig. 10.26 Occlusal (A), mid-tooth (B) and apical (C) sections from an infected 107 CT that has occlusal pulpar exposure of all 5 pulp chambers, which are filled with food down to the apex. The rostral infundibulum (r) has cemental caries, especially more apically. The caudal infundibulum (c) has central cemental hypoplasia with localized cemental caries. Infundibular caries was not found to penetrate the infundibular enamel at any level in either infundibulum, indicating that infundibular infection did not cause the apical infection in this tooth. Infection was ultimately attributed to anachoresis. (Reproduced from Dacre et al,⁵⁵ with permission of The Veterinary Journal.)

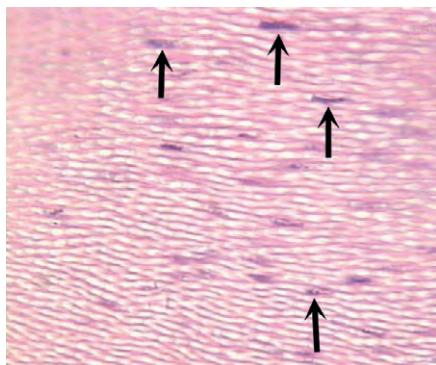


Fig. 10.27 Higher power image of decalcified transverse sub-occlusal section of dentin from an apically infected maxillary CT showing bacteria (arrows) present in obliquely-sectioned, primary dentin tubules (H&E x 400). (Reproduced from Dacre et al,⁵⁵ with permission of The Veterinary Journal.)

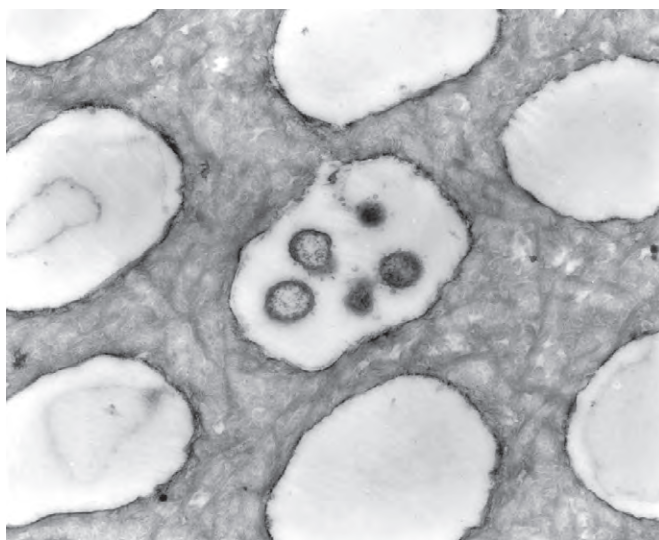


Fig. 10.28 Pioneer organisms (bacteria) are present within the central dentinal tubule in this transmission electron micrograph. Such microorganisms may invade down dentinal tubules and infect the pulp if the host defense mechanisms are inadequate.

age.⁶⁷ A recent study of 786 maxillary cheek teeth, from 33 horses (median age 10 years), that were sectioned longitudinally found that only 11 % of infundibula were completely filled with grossly normal cementum, and areas of cemental hypoplasia and cemental discoloration, respectively, were observed in 22 % and 72 % of infundibula.⁶⁸

Cemental hypoplasia of the infundibula can develop secondary to premature destruction of the dental sac, such as by premature removal or loss of overlying deciduous CT.³³ However, recent examinations of CT of 1–3 years *dental age* demonstrated the presence of a viable blood supply to the apex of infundibula, which was confirmed histologically⁶⁸ (see Chapter 5). This blood supply allows continued infundibular cemental deposition to occur (at least in the apical aspect of the infundibulum) for a few years following maxillary CT eruption. In that study, widespread infundibular cemental caries was found in 8 % (62/786) of infundibula, with the Triadan 09 positions disproportionately

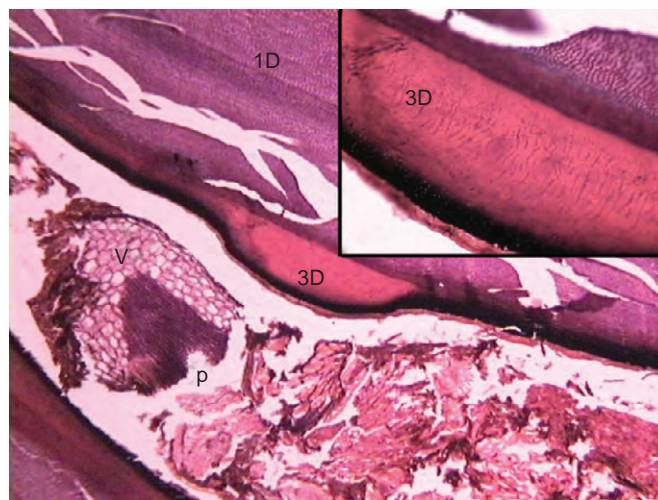


Fig. 10.29 Tertiary dentin (3D) has been laid down within the pulp of this equine cheek tooth in response to focal noxious stimuli. As seen more clearly in the insert (top right), there is no continuation of dentinal tubules into this tertiary dentin (as occurs between primary and secondary dentin). The pulp (p) has been exposed latterly through dental attrition resulting in the pulp horn filling with vegetable material (V), and destruction of any pulp that remained (decalcified transverse H and E section).

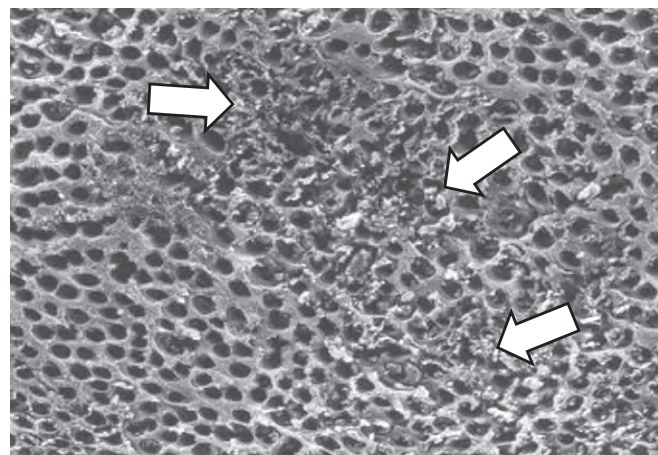


Fig. 10.30 Scanning electron microscopy image of carious dentin lining a pulp chamber that contains necrotic pulp. Many areas have localized loss of integrity of intertubular dentin (arrows). (Reproduced from Dacre et al⁵⁵ with permission of The Veterinary Journal.)

accounting for 47 % (29/62) of these carious teeth.⁶⁸ This prevalence of 8 % infundibular caries is much lower than reported by other authors,^{10,11,14,65,66} possibly due to classification of infundibular cemental hypoplasia as infundibular caries in some of these earlier studies.

The decalcified histological appearance of infundibular caries in donkey CT showed loss of normal cementum with the presence of necrotic material and vegetable matter in affected infundibula⁵⁹ (Fig. 10.33). Undecalcified histology demonstrated an extension of the carious process from the cementum to the infundibular enamel, resulting in a ragged appearance of the amelocemental junction instead of its normal smoothly scalloped appearance, indicating the presence of enamel demineralization.⁵⁹ Scanning electron microscopy also demonstrated extension of caries along the

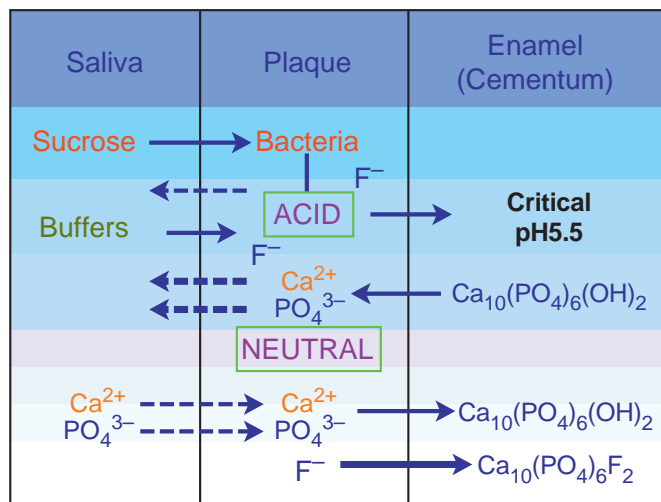


Fig. 10.31 Diagrammatic representation of principal biochemical aspects of factors influencing caries under acidic (pH < 5.5) conditions (favoring caries) following degradation on carbohydrates (e.g., sucrose) and at a neutral pH, e.g., following buffering by saliva.

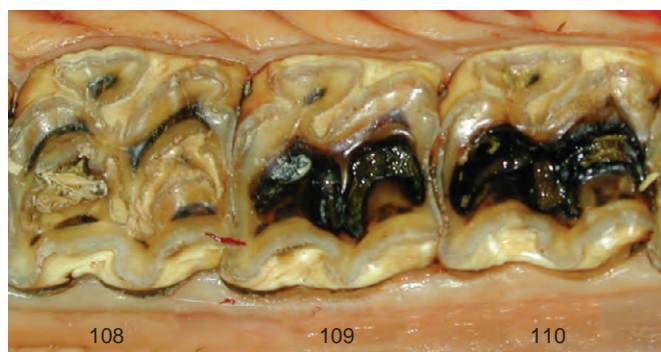


Fig. 10.32 Infundibular caries is present in both rostral and caudal infundibula of maxillary CT 109 and 110. The infundibula have not coalesced at this stage, but both the infundibular enamel and dentin between the two infundibula are carious.

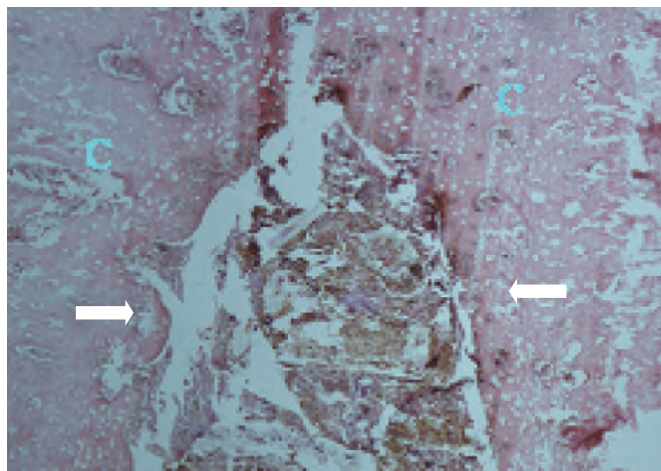


Fig. 10.33 Decalcified histological image of vegetable matter (arrows) lying in defective cementum within an equid cheek tooth infundibulum.



Fig. 10.34 High-power SEM image of the distal aspect of a longitudinal section of a 209 infundibulum showing carious changes (arrow) to the periphery of the cementum (C) with loss of the normal amelocemental junction. (Reproduced from du Toit et al,⁵⁹ with permission of *The Veterinary Journal*.)

Table 10.2 A grading system for equine dental caries

0 degree	No macroscopic visible caries (can include infundibular hypoplasia)
1st degree	Caries only affecting the cementum <ul style="list-style-type: none"> – from small pitting superficial spots (class 1) – extensive destruction and loss of cementum (class 2)
2nd degree	Caries affecting cementum and adjacent enamel
3rd degree	Caries affecting cementum, enamel and dentin
4th degree	Caries now affects the integrity of the tooth, i.e., development of an apical abscess or secondary tooth fracture

amelocemental junction resulting in destruction of cementum and enamel in the apical aspect of the infundibulum⁵⁹ (Fig. 10.34). Interestingly, studies have shown that caries in human dentin and enamel start with demineralization (due to low pH) of these tissues prior to bacterial infection, whereas in caries of cement, demineralization and bacterial infection occur simultaneously.⁶⁹ The above-noted equid cemental SEM studies⁵⁹ would also support these findings.

Infundibular caries has been classified by Honma⁴ according to the degree of its spread into different dental tissues. A modified classification of infundibular caries has been proposed by Dacre,³⁷ which is also applicable for grading peripheral caries in equine teeth (Table 10.2).

Caries of the peripheral aspect of the equine teeth (Figs 10.35 & 10.36), although apparently common, has been poorly described^{70,71} and as it most obviously involves the peripheral cementum it is sometimes termed *peripheral cemental caries*, which does not describe the full extent of this disorder. Peripheral dental caries may affect infolded peripheral cementum including cementum that lies on the occlusal surface, and therefore can predispose to an increased



Fig. 10.35 Widespread peripheral cemental caries of mandibular CT 309–311. Note how the caries has removed much of the supporting lingual cementum from the clinical crown of 311, leaving its discolored enamel.

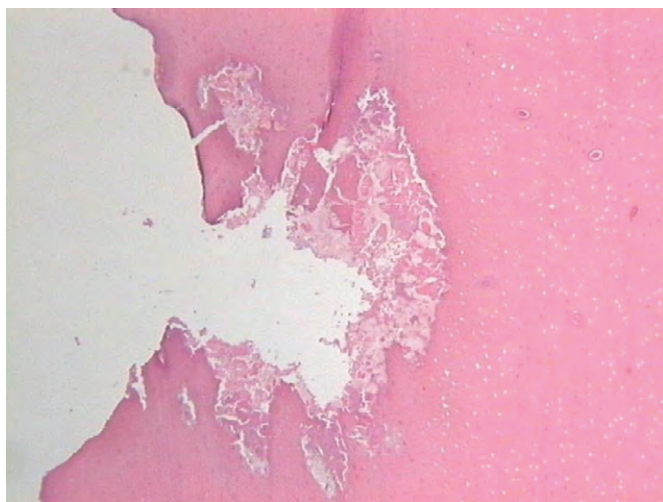


Fig. 10.36 Caries of peripheral cementum in a decalcified section from a mandibular CT. This shows the characteristic pitting nature of these lesions (H and E).

rate of occlusal wear and fracture of unsupported (brittle) enamel. By causing destruction of the normal peripheral cementum-periodontal attachments, peripheral caries can also initiate local periodontal disease. As noted earlier, infundibular cemental caries may extend through the enamel to dentin and pulp, resulting in apical infection.^{54,55,72} Infundibular caries can also extend concentrically along the inner (medial) aspect of the infundibular enamel – even causing coalescence of both infundibula that may be surrounded by tertiary dentin that seals off the pulp horns from the infection. Nevertheless, these processes can mechanically weaken the tooth and result in midline sagittal fractures of affected maxillary CT.⁶⁷

High levels of severe peripheral dental caries involving all classes of teeth (incisors, canines, and CT) have been found in groups of equids under certain management practices, such as feeding high concentrate, low roughage diets, where the reduced time spent masticating and decreased

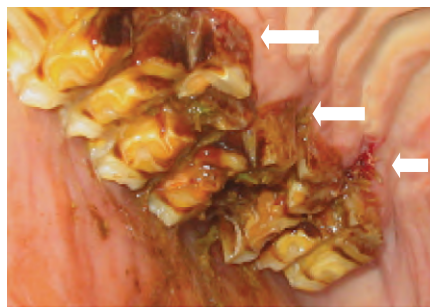


Fig. 10.37 Caudal maxillary cheek teeth from a horse with severe generalized peripheral caries and secondary fractures and periodontal disease associated with feeding an almost total processed maize diet.



Fig. 10.38 These incisors (from a horse on the same diet as the horse in Fig. 10.37) have multiple fractures due to generalized dental caries that was associated with feeding very high levels of a processed maize diet.

volume of buffering saliva may predispose to prolonged periods of low pH in the oral cavity and demineralization of calcified dental tissue. Peripheral caries is also concurrently found with other dental abnormalities, where restricted food and saliva movement may predispose to its development. Extensive generalized caries has also been recorded in horses fed diets with a low pH, where excessive acids were added to silage/haylage and also in diets consisting largely of simple carbohydrates, i.e., processed maize foodstuffs (Figs 10.37 & 10.38).

It is also likely that some individual horses are predisposed to peripheral dental caries. There is minimal published knowledge on the normal bacteriology of the equine mouth and even less on the bacteria that incite dental caries formation, and this is an area that needs urgent investigation.^{72,73}

Dental fractures

Traumatic dental fractures

Although the teeth of horses are largely composed of equine type-2 enamel that is relatively fracture resistant, traumatic

dental fractures, particularly of the incisors, are relatively common in horses, due to external trauma such as kicks, crib-biting, biting hard objects, and collisions with solid objects, e.g., gates, fences and walls.⁷⁴ Dixon et al¹¹ found that 8 of 11 referred cases with incisor fracture were caused by trauma. Equine CT are composed of high levels of hard but brittle equine type-1 enamel, with higher proportions of type-1 enamel in equine maxillary than mandibular CT.⁷⁵ Nevertheless, traumatic equine fractures of CT are less common than incisor fractures due to their anatomical protection (especially of maxillary and caudal mandibular CT). Only 8% of horses referred because of CT disorders had traumatic fractures, with the majority (71%) being mandibular CT fractures, with kick injuries and iatrogenic fractures (use of dental shears) being the most common causes of fracture. Traumatic CT fractures are usually accompanied by mandibular or maxillary bone fractures, which are covered in Chapter 9. Some fractured teeth can be preserved by endodontic therapy, as covered in Chapter 22.

Idiopathic cheek teeth fractures

The majority of equine CT fractures have no known history of trauma and have been classified as *idiopathic* CT fractures.⁷⁶ These fractures can be subtle and are sometimes not detected on oral examination. Nevertheless, with training they can commonly be found, with one practice-based survey indicating a median prevalence of 0.4% of idiopathic fractures in a mixed population of horses.⁷⁷ The clinical signs most commonly seen with dental fractures are quidding, followed by biting and behavioral problems, and halitosis.^{76,78} Some horses, especially those with smaller slab fractures, can be asymptomatic, and the fractures are only noted during routine dental examinations.⁷⁷ A pathological study of 35 CT with idiopathic fractures found that maxillary CT (in particular the maxillary 09s) were more commonly involved than mandibular CT, and a similar distribution was found in both general practice and referral clinic surveys,^{77,78} and in a pathological survey,⁷⁶ but the reason for this pattern is unknown. The most common fracture patterns in idiopathic CT fractures are lateral slab fractures through the two lateral (buccal) pulp cavities,⁷⁶⁻⁷⁸ possibly because the mineralized dental tissues are thinner at the sites of the pulp horns and, therefore, the CT are weakest at this point⁷⁶ (Figs 10.39 & 10.40).

A common fracture pattern in maxillary CT is a midline sagittal fracture through both infundibula in the CT with infundibular caries that, as noted, is believed to be predisposed by infundibular cemental hypoplasia.⁷⁶

Histological quantitative measurements of dentin showed reduced thickness of dentin in 25% of CT with idiopathic fractures, indicating prior pathological changes to pulp. Consequently, the resultant thinner dentin mechanically predisposes to fracture development in these particular CT.⁷⁶ Dental pulps are inevitably involved in all (maxillary and mandibular) idiopathic fractures, including the smaller maxillary CT 'slab' fractures.⁷⁶⁻⁷⁸ However, many lateral slab fractures, in particular, have been shown to clinically resolve without development of clinical apical infections,¹³ indicating that the resultant pulpitis remains low grade or that the underlying pulp has been sealed off from the fracture site by the deposition of tertiary dentin.⁷⁹ Many such fractured CT

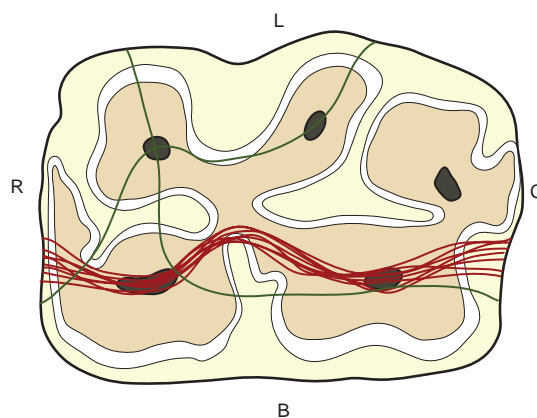


Fig. 10.39 Common patterns of idiopathic mandibular cheek teeth fractures. R, rostral; C, caudal; B, buccal; L, lingual. The most common fracture pattern (red lines) runs through the two pulp chambers on the buccal aspect of the tooth. (Reproduced from Dacre et al⁷⁶ with permission of *The Equine Journal*.)

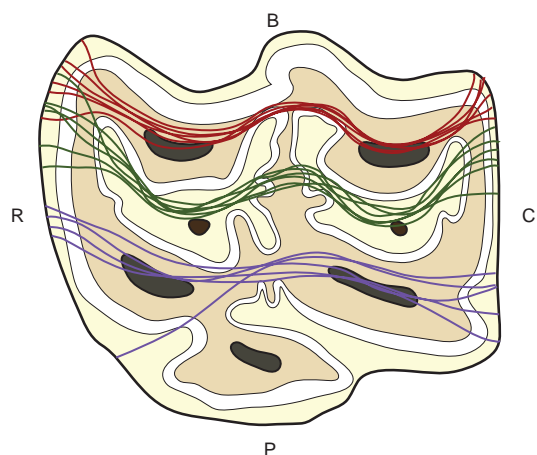


Fig. 10.40 Common patterns of idiopathic maxillary cheek teeth fractures. R, rostral; C, caudal; B, buccal; P, palatal. The two most common fracture patterns run through the two pulp chambers on the buccal aspect of the tooth (red lines) and through the infundibula (green lines). A variety of other fracture patterns can also occur through the other pulp horns (purple lines). (Dacre et al⁷⁶ with permission from *The Equine Journal*.)

that survive following an idiopathic fracture have long-term radiographic changes to their apical regions, and additionally have scintigraphic changes to this region (at least for some months following the development of fractures), indicating a widespread, but subclinical endodontic response to these CT fractures.

A proportion of fractured CT develop pulpar infection that extends to affect the apex clinically, with the resultant clinical signs depending on which tooth is involved (Figs 10.41 & Fig 10.42). Such clinical signs are common with maxillary CT midline sagittal fractures and mandibular CT fractures, and such CT require dental extraction. In other CT, mobility of one or more fragments causes periodontal stretching and pain during quidding until smaller dental fragments are spontaneously shed or until they are extracted. Other fractured CT develop food impaction into the fracture site causing lateral or, less commonly, medial displacement

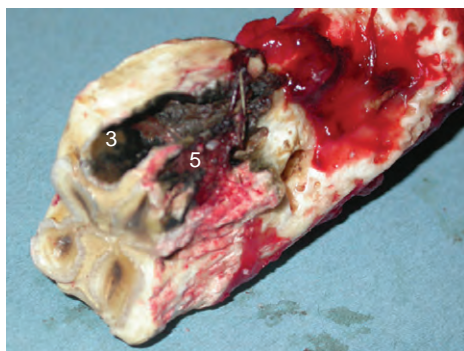


Fig. 10.41 Advanced caries of pulp horn 3 (3) which extends into pulp horn 5 (5) in this fractured mandibular CT. This fractured tooth was extracted orally and crush marks from the extraction forceps are seen on the buccal face of its clinical crown. Note the hyperplastic peripheral cementum on the reserve crown that has been laid down in response to the apical abscess present.

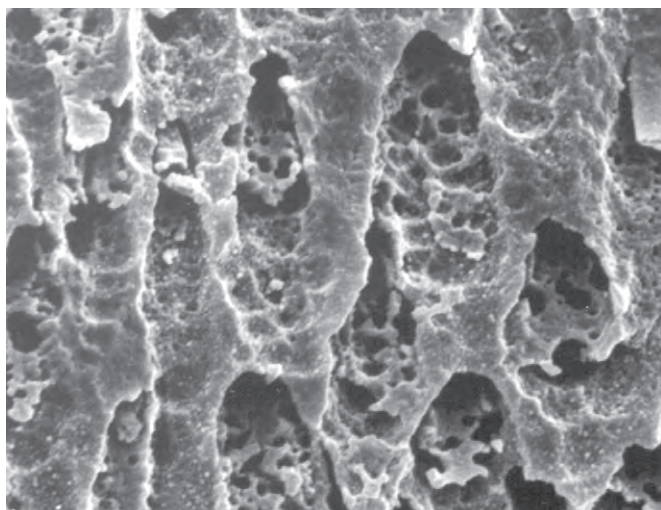


Fig. 10.42 A scanning electron micrograph of primary carious dentin present on a mandibular CT following a dental fracture. Note the fenestrated appearance of the carious dentinal tubules.

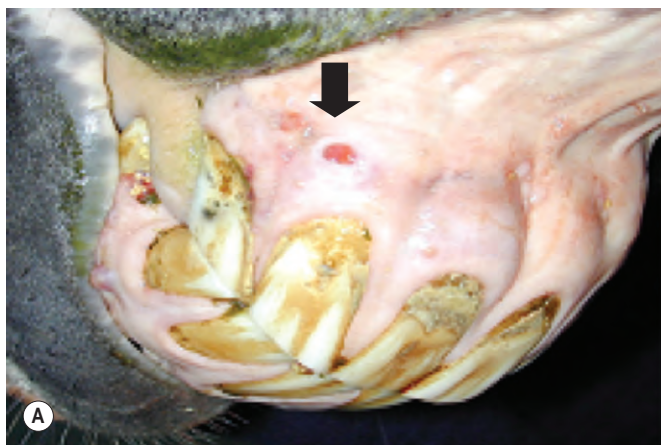


Fig. 10.43 (A) The incisors of this horse have extensive cemental deposition subgingivally, and some have sinus tracts (arrow) caused by EOTRH. (Courtesy of Højgaard Hestehospital.) (B) Radiograph of incisors of a 17-year-old pony that had marked gingival swelling without any sinus tracts, which shows very extensive hypercementosis of the reserve crowns of all incisors, with minimal destructive changes apparent. (Courtesy of M. Parr.)

of the more mobile, smaller fracture segment that causes soft tissue (usually buccal) ulceration and resultant quidding. Removal of the displaced fracture segment is indicated. Prevention of dental fractures secondary to infundibular caries has been attempted (especially in horses with pre-existing CT fractures) by removal of carious infundibular cementum and filling the infundibular defect with endodontic restorative materials, but objective research on this treatment needs to be performed to determine its value.

Equine odontoclastic tooth resorption and hypercementosis (EOTRH)

Recently, an uncommon disorder of incisor and canine teeth of aged horses, causing periodontitis, with resorptive or proliferative changes of the calcified dental tissue has been described by Klugh,⁸⁰ Baratt,⁸¹ Caldwell,⁸² and Kreutzer et al.⁸³ A pathological study of this disorder by Staszuk et al.⁸⁴ resulted in the disease being termed equine odontoclastic tooth resorption and hypercementosis (EOTRH). No plausible etiopathogenesis for this apparent immune-mediated syndrome has been described. The study by Staszuk et al.⁸⁴ found the disorder to primarily affect the intra-alveolar aspect of the teeth and showed the presence of odontoclastic cells in affected teeth by using tartar resistant acid phosphatase staining. These odontoclastic cells cause resorptive lesions extending into cementum, enamel, dentin, and even into pulp, causing marked loss of normal architecture in some teeth. In several areas, the resorbed areas and unaffected dental surfaces had irregular cementum deposition by cells of the periodontal ligament that led to hypercementosis in some areas (Figs 10.43 & 10.44).⁸⁴ The pulp chambers of some affected teeth had irregular cementum deposition over tertiary dentin lining the chambers. This disorder shares many features with similar dental syndromes described in people^{85,86} and cats,^{87,88} but in many affected horses, a massive proliferative hypercementosis of all incisors is the main feature,⁸⁹ in contrast with the more destructive syndrome observed in human and feline teeth.

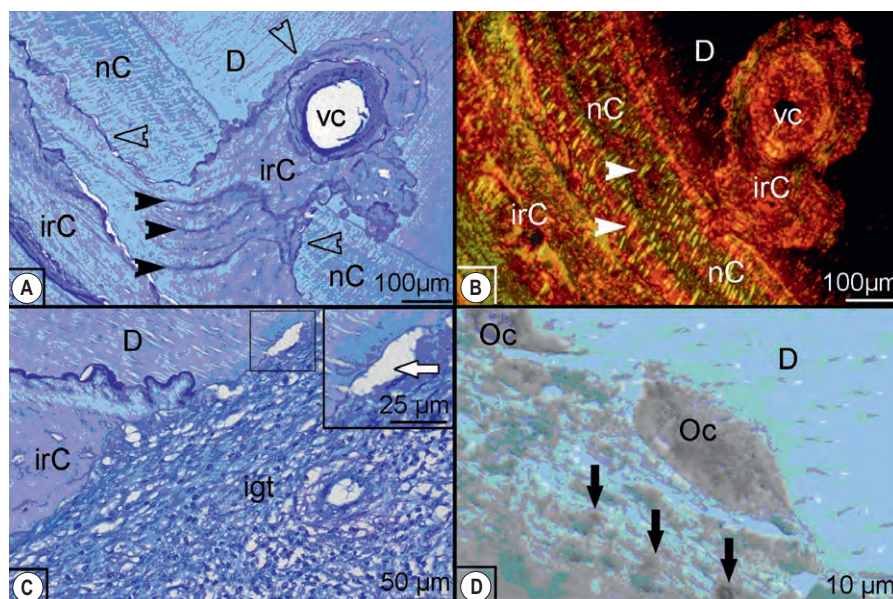


Fig. 10.44 (A) Toluidine blue-stained decalcified transverse section of the mid-tooth region of 103 of horse 5. Irregular cementum (irC) fills a deep resorptive lesion that extends into normal cementum (nC) and dentin (D). The border of the irregular cementum (irC) is marked by a reversal line (open arrowheads). Wavy incremental lines (black arrow heads) indicate irregular but phasic growth. This irregular cementum contains a large vascular channel (vc). (B) Subsequent serial section of above tooth stained with Picrosirius red showing concentric deposition of intrinsic collagen fibers around the vascular channel (vc). There is parallel arrangement of the extrinsic collagen fiber bundles (white arrow heads) within the normal cementum (nC). (C) Toluidine blue-stained decalcified transverse section of the mid-tooth region of 101 of horse 4. Irregular cementum (irC) deposited in a resorptive lesion. (Inset) The white arrow indicates an ongoing resorption process at the dentinal surface. igt: inflamed granulation tissue. (D) TRAP stained decalcified transverse mid-tooth section of a 101 of horse 4, showing TRAP-positive, multinucleated odontoclasts (Oc) lying in a Howship's lacuna at the dentinal surface (D). Mononucleates, precursors of odontoclasts (arrows) are located at a short distance behind the resorption surface. (Reproduced from Staszky et al.¹⁸⁴ with permission of *The Veterinary Journal*)

References

1. BEVA: British Equine Veterinary Association survey of equine diseases 1962–1963. *Vet Rec* 1965; 77: 528–538
2. Traub-Dargatz JL, Salman MD, Voss JL. Medical problems of adult horses, as ranked by equine practitioners. *J Am Vet Med Assoc* 1991; 198(10): 1745–1747
3. Uhlinger C. Survey of selected dental abnormalities in 233 horses. *Proceedings of the 33rd AAEP Annual Convention* 1987; 33: 577–583
4. Honma K, Yamakawa M, Yamauchi S, Hosoya S. Statistical study on the occurrence of dental caries of domestic animal: I. Horse. *Japanese Journal of Veterinary Research* 1962; 10: 31–36
5. Kirkland KD, Marretta SM, Inoue OJ, Baker GJ. Survey of equine dental disease and associated oral pathology. *Proceedings of the 40th AAEP Annual Convention* 1994; 40: 119–120
6. Wafa NS. A study of dental disease in the horse. MVM Thesis. University College Dublin, Dublin, 1988, p. 188
7. du Toit N, Gallagher J, Burden FA, Dixon PM. Post mortem survey of dental disorders in 349 donkeys from an aged population (2005–2006). Part 1: prevalence of specific dental disorders. *Equine Vet J* 2008; 40: 204–208
8. Penzhorn BL. Dental abnormalities in free-ranging Cape mountain zebras (*Equus zebra zebra*). *Journal of Wildlife Diseases* 1984; 20: 161–166
9. Baker GJ. Some aspects of equine dental disease. *Equine Vet J* 1970; 2: 105–110
10. Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease part 4: a long-term study of 400 cases: apical infections of cheek teeth. *Equine Vet J* 2000; 32: 182–194.
11. Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease part 1: a long-term study of 400 cases: disorders of incisor, canine and first premolar teeth. *Equine Vet J* 1999; 31: 369–377
12. Dixon P, Tremaine WH, Pickles K, et al. Equine dental disease part 2: a long-term study of 400 cases: disorders of development and eruption and variations in position of the cheek teeth. *Equine Vet J* 1999; 31: 519–528
13. Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease part 3: A long-term study of 400 cases: disorders of wear, traumatic damage and idiopathic fractures, tumours and miscellaneous disorders of the cheek teeth. *Equine Vet J* 2000; 32: 9–18
14. Brigham EJ, Duncanson GR. An equine postmortem dental study: 50 cases. *Equine Veterinary Education* 2000; 12: 59–62
15. du Toit N, Burden FA, Dixon PM. Clinical dental examinations of 357 donkeys in the UK. Part 1: Prevalence of dental disorders. *Equine Vet J* 2009; 41(4): 390–394
16. Hillson S. *Teeth*. Cambridge University Press, Cambridge, 1986, pp 176–186, 214–215
17. O'Connor JJ. *Dollar's Veterinary Surgery: general, operative and regional*, 4th edn. Baillière, Tindall and Cox, London, 1950, pp 590–603
18. Bonin SJ, Clayton HM, Lanovaz JL, Johnson TJ. Kinematics of the equine temporomandibular joint. *American Journal of Veterinary Research* 2006; 67: 423–428
19. Capper SR. The effects of feed types on ingestive behaviour in different horse types, in BSc Edinburgh, University of Edinburgh, 1992, p. 160
20. Bonin SJ, Clayton HM, Lanovaz JL, Johnston T. Comparison of mandibular motion in horses chewing hay and pellets. *Equine Vet J* 2007; 39: 258–262
21. Frape D. *Equine nutrition and feeding*, 3rd edn. Blackwell, Oxford, 2004, pp 1–3

22. Becker E. Handbuch der speziellen pathologischen anatomie der haustiere, 3rd edn. Verlag Paul Parey, Berlin, 1962, pp 121–133, 249–260, 263–265
23. Du Toit N, Burden F, Dixon PM. Clinical dental findings in 203 donkeys in Mexico. *Vet J* 2008; 178: 380–386
24. Tell A, Egenvall A, Lundström T, Wattle O. The prevalence of oral ulceration in Swedish horses when ridden with a bit and bridle and without. *Vet J* 2008; 178: 405–410
25. Baker GJ. Dental morphology, function and pathology. Proceedings of the 37th AAEP Annual Convention 1991; 37: 83–93
26. Brown SL, Arkin S, Shaw DJ, Dixon P. Occlusal angles of cheek teeth in normal horses and horses with dental disease. *Vet Rec* 2008; 162: 807–810
27. Kirkland KD, Baker GJ, Manfra Marretta S, et al. Effects of aging on the endodontic system, reserve crown, and roots of equine mandibular cheek teeth. *Am J Vet Res* 1996; 57: 31–38
28. Dixon PM, Dacre I. A review of equine dental disorders. *Vet J* 2005; 169: 165–187
29. du Toit N, Burden FA, Dixon PM. Clinical dental examinations of 357 donkeys in the UK. Part 2: Epidemiological studies on the potential relationships between different dental disorders, and between dental disease and systemic disease. *Equine Vet J* 2009; 41(4): 395–400
30. du Toit N, Gallagher J, Burden FA, Dixon PM. Post mortem survey of dental disorders in 349 donkeys from an aged population (2005–2006). *Equine Vet J* 2008; 40: 209–213
31. Townsend N, Dixon PM, Barakzai S. Evaluation of the long term consequences of equine exodontia in 50 horses. *Vet J* 2008; 178(3): 419–424
32. Lowder MQ, Mueller PO. Dental disease in geriatric horses. *Veterinary Clinics of North America Equine Practice* 1998; 14: 365–380
33. Dixon PM. The gross, histological, and ultrastructural anatomy of equine teeth and their relationship to disease. Proceedings of the 48th AAEP Annual Convention, 2002, pp 421–437
34. Collins SN, Dixon PM. Diagnosis and management of equine diastemata. *Clinical Techniques in Equine Practice* 2005; 4: 148–154
35. Dixon PM. Cheek teeth diastemata and impactions. Proceedings of the AAEP/BEVA Dental focus meeting. Indianapolis, 2006
36. Dixon PM, Barakzai S, Collins N, Yates J. Treatment of equine cheek teeth by mechanical widening of diastemata in 60 horses (2000–2006). *Equine Vet J* 2008; 40: 22–28
37. Dacre IT. Equine dental pathology. In: Baker GJ, Easley KJ, eds. *Equine dentistry*, 2nd edn. Elsevier, 2005, pp 91–110
38. Carmalt JL. Understanding equine diastema. *Equine Veterinary Education* 2003; 15: 34–35
39. Barakzai S, Dixon PM. A study of open-mouthed oblique radiographic projections for evaluating lesions of the erupted (clinical) crown. *Equine Veterinary Education* 2003; 15: 143–148
40. Miles AEW, Grigson C. *Coyler's variations and diseases of the teeth of animals*. Cambridge University Press, Cambridge, 1990, p. 672
41. Hofmeyr CFB. Comparative dental pathology (with particular reference to caries and paradental disease in the horse and the dog). *Journal of the South African Veterinary Medical Association* 1960; 31: 471–480
42. Wiggs RB, Lobprise HB. Periodontology. In: Wiggs RB, Lobprise HB, eds. *Veterinary dentistry: Principles & practice*, Lippincott-Raven, Philadelphia, 1997, pp 186–231
43. Cutress TW, Healy WB. Calcified deposits on sheep incisor teeth. *Journal of Dental Research* 1967; 46: 1363–1367
44. Spence JA, Aitchison GU, Fraser J. Development of periodontal disease in a single flock of sheep: clinical signs, morphology of subgingival plaque and influence of antimicrobial agents. *Research Veterinary Science* 1988; 45: 324–331
45. Ingham B. Abattoir survey of dental defects in cull cows. *Vet Rec* 2001; 148(24): 739–742
46. Little WL. Periodontal disease in the horse. *Journal of Comparative Pathology* 1913; 26: 241–249
47. Dacre IT. A pathological, histological and ultrastructural study of diseased equine cheek teeth. PhD Thesis. University of Edinburgh, Edinburgh, 2005, p. 324
48. Soames JV, Southam JC. *Oral pathology*, 2nd edn. Oxford University Press, Oxford, 1993, p. 322
49. Dacre IT, Kempson SA, Dixon PM. Pathological studies of cheek teeth apical infections in the horse. Part 1: Normal endodontic anatomy and dentinal structure of equine cheek teeth. *Vet J* 2008; 178: 311–320
50. Nanci A. Dentin-Pulp complex. In: Nanci A, ed. *Ten Cate's Oral histology: development, structure and function*. Mosby, St Louis, 2003, pp 192–239
51. Shaw DJ, Dacre IT, Dixon PM. Pathological studies of cheek teeth apical infections in the horse. Part 2: Quantitative measurements in normal equine dentine. *Vet J* 2008; 178: 321–332
52. Lane JG. A review of dental disorders of the horse, their treatment and possible fresh approaches to management. *Equine Veterinary Education* 1994; 6: 13–21
53. Dacre IT, Shaw DJ, Dixon PM. Pathological studies of cheek teeth apical infections in the horse. Part 3: Quantitative measurements of dentine in apically infected cheek teeth. *Vet J* 2008; 178: 333–340
54. Dacre IT, Kempson SA, Dixon PM. Pathological studies of cheek teeth apical infections in the horse. Part 4: Aetiopathological findings in 41 apically infected mandibular cheek teeth. *Vet J* 2008; 178: 341–351
55. Dacre IT, Kempson SA, Dixon PM. Pathological studies of cheek teeth apical infections in the horse. Part 5: Aetiopathological findings in 57 apically infected maxillary cheek teeth and histological and ultrastructural findings. *Vet J* 2008; 178: 352–363
56. van den Eden MAD, Dixon PM. Prevalence of occlusal pulpar exposure in 110 equine cheek teeth with apical infections and idiopathic fractures. *Vet J* 2008; 178: 364–371
57. Henninger W, Frame EM, Willman M, et al. CT features of alveolitis and sinusitis in horses. *Veterinary Radiology Ultrasound* 2003; 44: 269–276
58. Kilic S, Dixon PM, Kempson SA. A light microscopic and ultrastructural examination of calcified dental tissues of horses: 3. Dentine. *Equine Vet J* 1997; 29(3): 206–212
59. du Toit N, Burden FA, Kempson SA, Dixon PM. Pathological investigation of caries and occlusal pulpar exposure in donkey cheek teeth using computerised axial tomography with histological and ultrastructural examinations. *Vet J* 2008; 178: 387–395
60. Dixon PM. How do periapical infections develop in the horse? Fifth World Veterinary Dental Congress, Birmingham, 1997, pp 130–134
61. Masset A, Staszuk C, Gasse H. The blood vessel system in the periodontal ligament of the equine cheek teeth—part I: The spatial arrangement in layers. *Ann Anat* 2006; 188(6): 529–533
62. Tremaine WH. Dental endoscopy in the horse. *Clinical Techniques in Equine Practice* 2005; 4: 181–187
63. Simhofer H, Gross R, Zetner K. The use of oral endoscopy for the detection of cheek teeth abnormalities in 300 horses. *Vet J* 2008; 178: 396–404
64. Wiggs RB, Lobprise HB. Clinical oral pathology. In: Wiggs RB, Lobprise HB, eds. *Veterinary dentistry: principles and practice*. Lippincott-Raven, Philadelphia, 1997, pp 112–116
65. Kilic S, Dixon PM, Kempson SA. A light microscopic and ultrastructural examination of calcified dental tissues in horses: 4. Cement and the amelocemental junction. *Equine Vet J* 1997; 29: 213–219
66. Colyer JE. Variations and diseases of the teeth of horses. *Transaction of the odontological society of Great Britain* 1906; 38: 42–74

67. Baker GJ. Some aspects of equine dental decay. *Equine Vet J* 1974; 6: 127–130
68. Fitzgibbons C, du Toit N, Dixon PM. Anatomical studies of equine cheek teeth infundibulae. *Equine Vet J* 2010; 42: 37–43
69. Frank RM. Structural events in the caries process in enamel, cementum, and dentin. *Acta Zoologica Fennica* 1990; 180: 1–76
70. Baker GJ. Dental disease in horses. In practice: *Journal of Veterinary Postgraduate Clinical Study* 1997; 1: 19–25
71. Easley KJ. Recognition and management of the diseased equine tooth. *Proceedings of the 37th American Association of Equine Practitioners Annual Convention* 1991; 37: 129–139
72. du Toit N. Equine peripheral and generalised caries – are they really a problem? *Proceedings of the 46th BEVA Congress Edinburgh*, 2007, pp 367–368
73. Lundstrom TS, Dahlen GG, Wattle OS. Caries in the infundibulum of the second upper premolar tooth in the horse. *Acta Veterinaria Scandinavia* 2007; 28: 10
74. Hague BA, Honnas CM. Traumatic dental disease and soft tissue injuries of the oral cavity. *Veterinary Clinics of North America Equine Practice* 1998; 14: 333–347
75. Kilic S, Dixon PM, Kempson SA. A light microscopic and ultrastructural examination of calcified dental tissues of horses: 2. Ultrastructural enamel findings. *Equine Vet J* 1997; 29: 298–305
76. Dacre I, Kempson SA, Dixon PM. Equine idiopathic cheek teeth fractures. Part 1: pathological studies on 35 fractured cheek teeth. *Equine Vet J* 2007; 39: 310–318
77. Taylor L, Dixon PM. Equine idiopathic cheek teeth fractures. Part 2: a practice based survey of 147 affected horses in Britain and Ireland. *Equine Vet J* 2007; 39: 322–326
78. Dixon PM, Barakzai S, Collins NM, Yates J. Equine idiopathic cheek teeth fractures. Part 3: A hospital based survey of 68 referred horses (1999–2005). *Equine Vet J* 2007; 39: 327–332
79. Magloire H, Joffe A, Bleicher F. An in vitro model of human dental pulp repair. *J Dent Res* 1996; 75(12): 1971–1978
80. Klugh DO. Incisor and canine periodontal disease. In: *Proceedings of the 18th Annual Veterinary Dental Forum*, Fort Worth, USA, 2004, pp 166–169
81. Baratt RM. Equine incisor resorptive lesions. In: *Proceedings of the 21st Annual Veterinary Dental Forum*, Minneapolis, USA, 2007, pp 23–30
82. Caldwell LA. Clinical features of chronic disease of the anterior dentition in horses. In: *Proceedings of the 21st Annual Veterinary Dental Forum*, Minneapolis, USA, 2007, pp 18–21
83. Kreutzer R, Wohlsein P, Staszuk C, Nowak M, Sill V, Baumgartner W. Dental benign cementomas in three horses. *Vet Pathol* 2007; 44: 533–536
84. Stazyk C, Bienert A, Kreutzer R, Wohlsein P, Simhofer H. Equine odontoclastic tooth resorption and hypercementosis. *Vet J* 2008; 178: 372–379
85. Moody GH, Muir KE. Multiple idiopathic root resorption. A case report and discussion of pathogenesis. *Journal of Clinical Periodontology* 1991; 18: 577–580
86. Schätzle M, Tanner SD, Bosshardt DD. Progressive, generalized, apical idiopathic root resorption and hypercementosis. *J Periodontol* 2005; 76: 2002–2011
87. Gorrel C, Larsson A. Feline odontoclastic resorptive lesions: unveiling the early lesion. *Journal of Small Animal Practice* 2002; 43: 482–488
88. Reiter AM, Mendoza KA. Feline odontoclastic resorptive lesions an unsolved enigma in veterinary dentistry. *Veterinary Clinics of North America Small Animal Practice* 2002; 32: 791–837
89. Gregory RC, Fehr J, Bryant J. Chronic incisor periodontal disease with cemental hyperplasia and hypoplasia in horses. *Proceedings of the AAEP/BEVA Dental focus meeting*. Indianapolis, 2006

Oral and dental tumors

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Introduction

Any tissue can develop neoplastic changes, and the structures of the mouth, including the soft tissues, the bone, and the teeth, are no exception. In general, however, this is an area of equine clinical oncology that has been largely ignored in spite of its importance to eating and its usually high visibility. Moreover, most published reports of specific oncologic conditions involve single or few cases, or are broad reviews based on these.^{1–4}

In common with other neoplastic disease, primary oral and dental tumors are usually classified according to their tissue of origin as (Fig. 11.1):

1. Dental (odontogenic) tumors
2. Bone (osteogenic) tumors
3. Soft-tissue tumors

and according to their clinical behavior and pathologic features as:

1. Benign or malignant
2. Invasive or localized and defined
3. Proliferative or ulcerative.

As with almost all equine cancerous conditions, there is no meaningful information on any tumor staging of any of the orodental tumors of horses. The tissue of origin, the location of the tumor, the extent of secondary tissue involvement, and the clinical and pathologic tumor behavior all inevitably have a profound effect on the feasibility and choice of treatment, as well as the prognosis for the horse.

When orodental neoplasms occur, they are often clinically important and can in many cases be life-threatening.⁵ Whilst some such tumors are recognized rapidly, the majority are not; often the secondary changes, such as weight loss or difficulty with eating (dysmasesis) are the main reason for presentation. Even the most astute owners may not notice oral lesions in their early stages, and so, many tumors are in an advanced state when first presented. This makes the general diagnosis of neoplasia relatively straightforward, but rather disappointing in most circumstances, since treatment options are then extremely limited.⁶ Additionally, since the gross appearance of many neoplastic masses in their early and advanced states can be similar, the definitive diagnosis inevitably depends on histological examination.⁷

An added complication is that some non-neoplastic oral conditions, such as epulis, gingival hyperplasia, granulation tissue, and hamartoma can give the clinical suspicion of neoplasia. Indeed, some masses have histological features that support a diagnosis of neoplasia but are not, in fact, cancerous.^{8–10} For example, fibrous metaplasia of the nasal region and hard palate have been described,^{11,12} and benign neoplastic growths are seen occasionally in association with abnormal germinal tissue of tooth apices¹³ (Fig. 11.1). These include:

- Papilloma
- Epulis
- Polyp
- Aneurysmal bone cyst
- Fibrous dysplasia/metaplasia.

There are also some cystic dentigerous disorders that may easily be mistaken for neoplasia.

Histological confirmation of the exact nature of oral tumors may prove difficult for a number of reasons. Both soft tissue and osseous and odontogenic tumors may be complicated by concurrent, long-standing infection or granulation tissue proliferation that may mask the true nature of the underlying lesion. Secondly, some of the hard tissue oral tumors are extremely difficult to biopsy and then to process for histopathologic examination. The rather variable classification of oral lesions also makes initial assessment of tumors difficult. Some tumors fall into the undifferentiated or unclassifiable myxoma/spindle-cell tumor group,¹⁴ which have ill-defined histological characteristics and variable clinical features. The variation in classification of equine tumors makes the specific diagnosis of many clinically obviously neoplastic diseases difficult and is further affected by the variable interpretation of different pathologists. It has to be recognized, however, that oral and dental tumors are relatively uncommon. This means that individual pathologists are unlikely to have an extensive database of experience of neoplasms at this anatomical site. It also means that careful consideration and appropriate sample collection are essential.

Although there have been some advances in the management of many neoplastic conditions in the horse, the low incidence of oral tumors makes it difficult to define the best approach to any particular tumor, and there is a lack of comparative evidence-based efficacy studies for the various

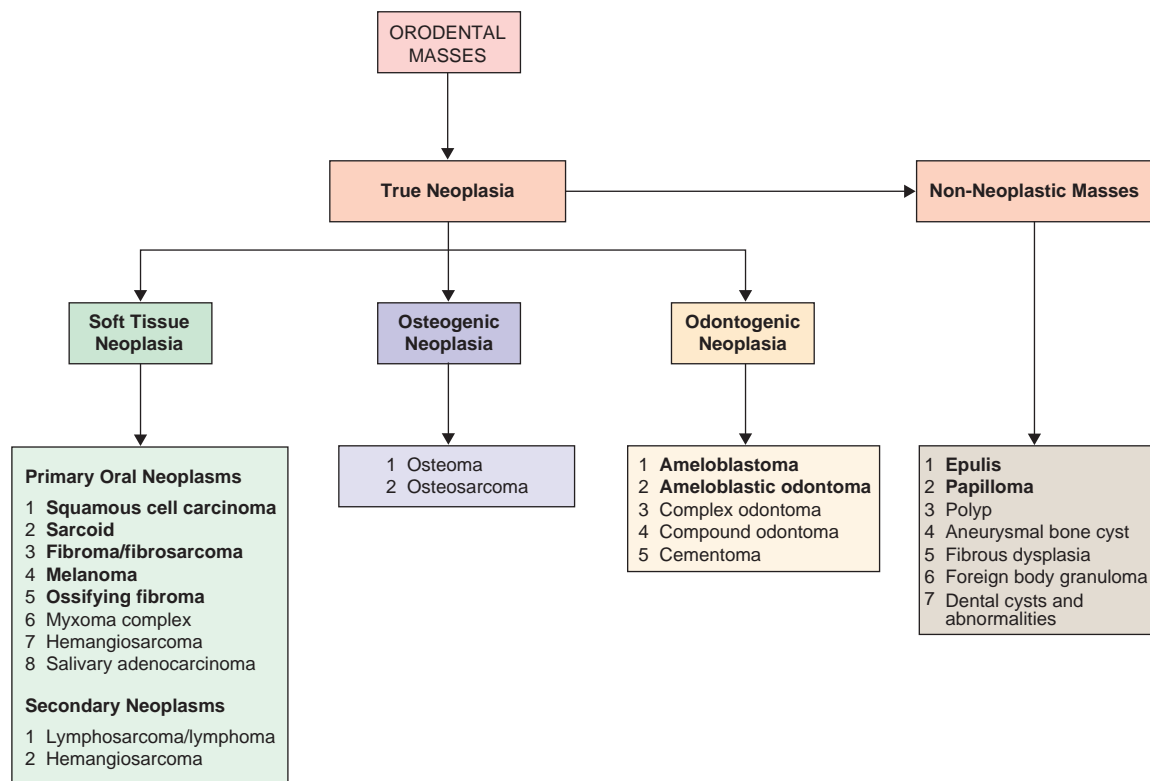


Fig. 11.1 Classification of orodental masses in the horse. The most common lesions are shown in bold font.

therapeutic options. Treatment options may also be affected by the delayed detection of tumors. Many have a benign character, but their size may make them impossible to treat by currently available means. Clinicians frequently have to make compromises from the ideal treatment options. The early diagnosis of an untreatable condition may not always be in the horse's best interests, since euthanasia may be performed before it is strictly necessary on welfare grounds, thus depriving the horse of some additional quality life and the owner of enjoyment. Often insurance and financial considerations take priority over the welfare issues.

Considering that most cases are presented late in the course of disease, determining the prognosis for a particular case is frequently the primary objective of the clinician, rather than providing any realistic treatment. Owners are generally more concerned with the prognosis than with the disease itself, but some expect treatment to be successful in every case. As most of these conditions are rare (or very rare), a realistic and objective prognosis, with or without treatment, may be difficult to provide. The course of most orodental tumors is unpredictable, and so the prognosis frequently becomes very subjective. Further, it is unfair to expect a pathologist to provide an accurate prognosis when there are few recorded cases of individual tumor type, and extrapolation from other species is usually not justified. However, more frequent reporting has improved the understanding of most equine neoplastic disease from both clinical and pathological perspectives.

Some oral neoplasms are very destructive, and so there may be extensive secondary changes that are more obvious

than the underlying condition. Also, neoplastic tissue is more susceptible to infection and trauma, and so the clinical appearance may be more severe than the tumor alone warrants. These factors have a considerable bearing on the ability to diagnose the oral lesions simply from clinical supposition and experience.

There are few pathognomonic signs for any particular type of tumor apart from the distinctive visual appearance of some conditions. The general presenting signs encountered, which are often subtle in the early stages, include:

1. Gross appearance of an abnormal mass of tissue, or secondary anatomic alterations due to proliferation or destruction of tissue within the oral cavity or adjacent structures, such as the cheeks, nasal cavity, and paranasal sinuses
2. Oral bleeding (manifest as hemosalivation or melena)
3. Dysprehesion / dysmasesis (dysmastication) / dysphagia
4. Weight loss
5. Recurrent fever and depression
6. Halitosis.

For example, oral carcinoma can result in loss of buccal sensation, and so the horse may suffer from significant self-trauma to the soft tissues of the mouth. A destructive oral carcinoma involving the palate may produce an oronasal fistula that might be recognized first by the presence of a nasal discharge, with or without overt food material. A space-occupying mass in the mouth may simply present with anatomic distortion and some functional deficits.

Investigation of a suspected oral mass should always begin with a detailed clinical history. A physical examination should be performed to establish both the clinical nature and extent of the neoplasm, to identify the structures involved, and to try to assess whether these changes are primary or secondary. A relatively small lesion in the mouth or adjacent structures may be secondary to a much more extensive lesion elsewhere. A good example of this is lymphosarcoma – the oral or pharyngeal lesions may be clinically insignificant, yet there can be extensive internal organ involvement.

Biopsy of any suspected neoplastic lesion is the mainstay of investigation. While biopsy of a suspect mass is frequently performed, it should be preceded by investigations that help to establish the extent and possible nature of the condition. For example, it may be very important to know if bone or other structures are involved, and this may influence both the site of biopsy and the method required to obtain diagnostic material. In many cases, it is useful to consult with a pathologist before performing a biopsy to ensure that the best diagnostic specimens are obtained and also so that the pathologist can orientate the specimens correctly in the context of precise anatomic location.

The prognosis varies markedly with the specific characteristics of the tumor. In some cases, these may not be the same as the classical description in other species. For example histopathology may suggest high malignancy, but the tumor may show no clinical evidence of this behavior. The converse situation can also arise.

Diagnostic procedures for suspected neoplastic disease

1. Radiography is the standard imaging method in the practice situation (see Ch. 13). These two-dimensional images do, however, create some interpretative difficulties. Where radiography is the only available imaging modality, carefully positioned images can be a major diagnostic help and a satisfactory diagnosis can be achieved or at least assisted in many cases. Unless experienced, it is useful to have a reference book available on normal radiographic variation because interpreting radiographs of the equine head can be difficult. Oblique projections can be helpful and fluoroscopy can be a significant aid in both diagnosis and treatment of head tumors. Contrast angiography can be a useful aid to surgical and possibly medical therapy, especially in aggressive tumors with large blood supplies.
2. Computed tomography (CT) is becoming increasingly available in veterinary practice and can now be performed on the standing sedated horse. It provides a three-dimensional radiograph and is particularly valuable for those conditions that are difficult or impossible to palpate or inspect (such as tumors within the paranasal sinuses or those associated with the teeth). CT images also help to establish the presence or absence of any secondary changes in the bone and other structures. This gives a greatly improved appreciation of the extent and nature of the challenges and complications likely to be faced by the surgeons in particular (see Ch. 13).

3. Magnetic resonance imaging (MRI) is an ideal modality for imaging soft tissues, and whilst the facilities for this are currently limited, they are increasing. MRI imaging suffers from the need for immobility and takes a considerable time to perform; therefore, general anesthesia is almost compulsory. Again, a three-dimensional image can be generated, and this greatly helps in dealing with soft tissue tumors and other masses within sites that preclude full inspection. The full extent of the tumor and its anatomic relationships can be revealed (Fig. 11.2).
4. Gamma scintigraphy:
 - (a) Gamma scintigraphy can currently be used in a non-specific way to identify small and large foci of tissue inflammation; the detection of a focus in either soft tissue or bone phase scans presently has low specificity as it simply identifies areas of tissue remodeling and inflammation. Nevertheless, the images derived can be dramatic.
 - (b) With increasing interest in monoclonal technology using radiolabeled antibodies, it is entirely reasonable to expect that this method may in future be added to the investigative list.
5. Ultrasonography:
 - (a) Ultrasonography is becoming increasingly valuable as more sophisticated equipment is developed. The details obtained of soft-tissue masses can be remarkable.
 - (b) Clearly, there are limitations in the head region relating mainly to the superficial bones, but soft tissue structures, such as the tongue, cheeks, and orbit, can be usefully examined.



Fig. 11.2 This oro-nasal palatine carcinoma was subjected to MRI scanning, and the 3-dimensional images significantly assisted the assessment of the options available to the clinician. (Courtesy A.J. van den Belt.)

- (c) In some cases the nature of the tumor/mass can be identified, e.g., soft-tissue masses can easily be differentiated from those involving bone, and some tumors, such as melanoma, have strongly suggestive, ultrasonographic characteristics.
 - (d) The blood supply to the mass can sometimes be identified, and this may provide useful therapeutic information.
6. Direct examination and endoscopy:
- (a) Oral examination whilst using a head-mounted, bright light source is helpful in many cases, but the most caudal teeth and the oropharynx may be obscured, especially if there are significant tissue distortions, either directly or secondarily due to the tumor. Sedation is invariably very helpful. A useful range of gags, mirrors, endoscopes, and specula are now available, and there can be little excuse for an inadequate visual inspection of the mouth (see Ch. 12).
 - (b) Oral endoscopy with a flexible endoscope is a risky procedure in the conscious standing horse – even when the horse is sedated. There may be logical reasons to perform this under general anesthesia (both to protect the equipment and to ensure a thorough examination), but the use of rigid intra-oral endoscopes has been well described in the standing horse. Suspect lesions can be biopsied via the endoscopic channel using suitable forceps. However, transendoscopic biopsy specimens have limited value since they are so small, and they are very liable to artefactual distortion during collection, such that a reliable diagnosis may be frustrated. Often it is only possible to obtain a biopsy from the most superficial parts of the tumor, and the specimen may contain granulation tissue, necrotic tissue, and areas of superficial infection and inflammation.
 - (c) Nasal endoscopy can be very helpful in identifying tumors that involve both the oral cavity and the nasal cavity or paranasal sinuses. Percutaneous sinusoscopy is a useful and simple procedure that can be performed via a small trephine in the wall of the affected sinus. Retrograde endoscopy via a tracheostomy can also be helpful in a few cases and is a relatively easy and safe procedure that is usually well tolerated by the horse.
7. Hematology and biochemistry:
- (a) Hematological findings are seldom specific in neoplastic diseases but anemia (deriving from chronic inflammation, paraneoplastic syndromes, or persistent bleeding) and alterations in leukograms may confirm that there are significant secondary effects. Localized tumors usually present no significant specific hematological changes. Anemia is a common feature of the paraneoplastic syndrome in horses, but most primary oral tumors have little or no effect on the major body systems. Ulcerative oral conditions usually result in hemoptyalism (presence of blood in saliva) which, even in microscopic amounts, can be detected simply using a urine dipstick. It is, however, obviously a very non-specific test.
 - (b) Non-specific changes, including hyperfibrinogenemia, hypoalbuminemia, and occasional evidence of the paraneoplastic syndrome (including hypercalcemia and organ failure), can be variable hematological markers.
 - (c) No specific circulating tumor markers have been identified for horses yet, but it is likely that these will be found in time. Whether it is helpful, however, to have a very early marker for a serious tumor type is a debatable point since localization and then treatment of the tumor may be major problems.
8. Biopsy is inevitably the most reliable method of establishing a definitive diagnosis. Accessibility is not usually a major obstacle with orodental tumors, but specialist approaches including trephination of sinuses and ultrasound or fluoroscopic guidance may be helpful. Biopsy of a suspected neoplastic mass can be achieved in several ways, including:
- (a) Excisional biopsy. The whole gross lesion is removed and examined. There are risks in this process but also benefits: in the event that total excision is achieved, the prognosis is excellent. However, failure to remove all the tumor or contamination of the wound site with tumor cells during surgery can be potentially serious. For example, the equine sarcoid may be removed safely in a few cases but total excision is seldom achieved, and seeding of the wound with tumor cells during the surgery can result in numerous new satellite lesions at the original site.
 - (b) Wedge or sectional biopsy. A small portion of the tumor is removed solely to establish the diagnosis. A rational approach can then be made to treatment selection. It is important to try to select viable and representative tumor tissue and to avoid areas that are ulcerated or necrotic, since such tissues are less likely to yield diagnostically useful information. Biopsy of non-typical regions can be helpful if the tumor is complicated by infection and granulation tissue and so, in some circumstances, obtaining several biopsies can be helpful. In this event, it may be possible to photograph the lesion and identify the sites of biopsy as an aid to the pathologists.
 - (c) Hollow needle (Trucut) biopsy. This method is used to obtain a core biopsy through the lesion with minimal damage to the overlying skin or mucosa. A specific location can be selected clinically or by ultrasonography, radiography, or computed tomography. This method has significant advantages in creating minimal trauma, but the samples are often

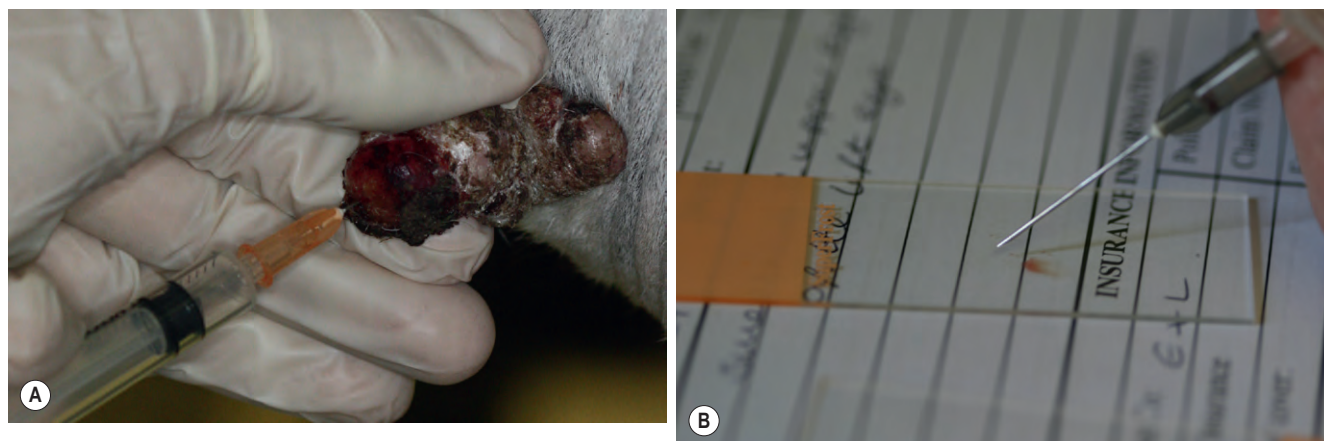


Fig. 11.3 (A) Fine needle aspiration requires no specialized equipment. It is best performed with a fine needle 23-g and a small 2-ml syringe. A fine needle is inserted into the margin of the lesion, and suction is applied via a 2-ml syringe 3–4 times. (B) The collected tissue should be jetted on to a clean slide, and air dried rapidly. The slide is identified with a pencil and sent directly to a cytologist. Alcohol fixation may be required.

small and artefactually damaged, and it is difficult to be sure that representative specimens are obtained. Again, ultrasonographic or fluoroscopic guidance can be helpful. Of course, there are significant physical difficulties in sampling bone and tooth and, as noted, processing the specimens is frequently problematic.

- (d) Fine needle aspiration. This is almost atraumatic to the tumor, and so there are reduced risks of significant tumor interference. A soft or fluid-filled mass can usually be aspirated with an 18-gauge needle (or finer). However, the technique of fine needle aspiration of solid tumors is often performed badly, and the specimens are often handled badly – collection of aspirated cells must be performed with care. Poor specimen handling means that the method has a poor reputation that is not entirely justified. Tumors vary in the ease with which they are aspirated, and so cytology may not always support a firm diagnosis.

The best fine needle aspiration technique involves the use of a small-gauge needle (21-g or less) and a small syringe (2-ml ideally; Fig. 11.3). Larger needles may seem an attractive option but usually they will harvest blood and gross tissue from the vicinity of the tumor and this is not helpful diagnostically – a few good cells, properly collected are far more useful than a few cells submerged in a large amount of necrotic tissue and blood. The needle should be inserted into the margins of the lesion – not the center, as many tumors have a necrotic center, and so, at that site, tumor cells may be degenerate, or non-specific inflammatory cells may be abundant. The best technique involves only 3–5 suction efforts with a maximum vacuum volume of 2 ml. Greater vacuum is not achieved with a bigger syringe! Furthermore, prolonged or marked vacuum pressures may damage cells significantly! The needle is then withdrawn, and the point

of the needle is directed at a clean, grease-free, glass microscope slide and the cells ‘jetted’ onto it by repeated ejection of air from the syringe. Several samples can be taken, and some can be spread onto the slide, and others simply left in situ. Thick preparations should be smeared immediately before being rapidly air-dried and fixed according to the requirements of the pathologist. An important practical consideration for cytology is to ensure that smears are not exposed to formalin fumes since the latter spoil cellular preparations for subsequent staining with Romanowsky cytological stains. It is best to identify the slides by writing on the frosted area with a pencil before the smears are made; markings made with a pencil will remain during alcohol fixing, and the pathologist will know which is the correct side of the slide to look at, even if there are only a few cells!

Interpretive cytology is best performed by a skilled cytopathologist because low numbers of tumor cells may not be easily recognized among normal cells.

Specimens that are obtained via endoscopic biopsy instruments have limited value since they are so small, and because they are liable to artefactual distortion during collection; a reliable diagnosis may not be obtained. Often it is only possible to obtain a biopsy from the most superficial parts of the tumor and the interpretation may be confused by the presence of granulation tissue, necrosis, superficial infection, and inflammation around the tumor.

Useful information can sometimes also be derived from impression smears made from ulcerated tumors. The same principles apply here – it is far better to have several slides with a few cells than one with a thick cellular accumulation. Impression smears can be improved by gently blotting the ulcerated surface of the tumor with clean paper towel, to remove extraneous cells and excess fluid, and if possible, by gentle squeezing of the tumor itself.

Notwithstanding the specific tests that can be applied in the investigation of oral and dental tumors, most of the commoner tumors are fairly distinctive, and a tentative diagnosis can usually be made by intuitive supposition. Problems may, however, arise with rarer tumors and those with prominent secondary inflammation and necrosis.

General principles of differential diagnosis

Oral tumors are conveniently divided into:

1. Primary tumors (of dental, soft tissue, or bone origin)
2. Secondary tumors (of non-odontal tissues)
3. Tumors of adjacent structures and associated organs invading into the oral cavity or its associated structures.

Secondary tumors with primary lesions elsewhere and tumors invading the mouth from adjacent structures such as the skin, the paranasal sinuses, and the nasal cavity must be considered when investigating an oral mass since identifying the origin might be diagnostically helpful and may have therapeutic implications. For example, a destructive nasal adenocarcinoma might invade the hard palate, creating an oronasal fistula and loosening some of the teeth. It would then be pointless to attempt to deal with the oral aspect of the tumor alone (even if there was some method to do this).

The lack of reported series of individual oral tumors and tumor-like masses testifies to the fact that most of these conditions are uncommon^{16–19} and that no significant attempt has been made to classify them and to quantify their prevalence through multicenter studies. The specific difficulties that are presented by the tumors and their profound effects (whether benign or malignant) mean, however, that veterinarians are expected to make prognostic decisions that are inevitably based on limited experience rather than sound, evidence-based principles. Recommendations for treatment of rare conditions cannot be made with any certainty, and pathologists are often expected to provide information that simply does not exist. The reported satisfactory or unsatisfactory treatment of a single case does not entitle pathologists or clinicians to refer to ‘common’ treatment or ‘usual’ tumor behavior.

General principles of management for neoplastic disease

Ideally, of course, any diagnosis of a neoplastic disease would be followed by a timely and specific curative therapy. However, the nature of the condition, the almost inevitably high cost of treatment and the owner’s attitude have a significant bearing on the choice of treatment. Often, treatment is not attempted because of one or more of these factors. Progress is being made in the management of tumors in many veterinary species but the improvements in equine oncology have been disappointingly slow. This may reflect the fact that, on most occasions, a diagnosis is made very late in the course of the condition, and so at initial presentation the prognosis is sufficiently poor to warrant euthanasia. Also, anti-cancer medications are expensive and particularly so for large horses. There is a general opinion that horses do not tolerate systemic chemotherapy well. The secondary (unwanted or side-) effects of most systemic anti-cancer therapy mean that few owners and veterinarians are willing to subject a horse to their side-effects. Surgical options are necessarily limited by facilities, access to the tumor, and the possibility of unacceptable functional problems after the surgery.

An additional and severely limiting aspect is, of course, whether the tumor has already metastasized. Where this has occurred, palliative treatment can still be carried out to improve the short-term quality of life, but the prognosis is by then very poor. Even when some tumors have spread beyond the oral cavity, the horse might not warrant immediate destruction since, in some circumstances, the metastases may have few effects and may be slow-growing. It is clear that some procedures, such as hemimandibulectomy, and removal of part of the tongue can be well tolerated by many horses. All treatment modalities have inherent limitations, and these simply have been accepted as part of the overall case management.

Surgery

The limitations of all treatment modalities, and particularly surgery, are well recognized. Limitations relate to accessibility and the associated problems of defining the margins of a tumor to ensure its total removal. Often the margins cannot be defined, and the constraints of the oral cavity mean that there is less scope for removal of extra tissue to achieve a safer margin, and so recurrence almost inevitably occurs. When surgery of any type is performed, all of the tissues removed should be submitted for histological examination, and the risk of failure to achieve an adequate margin should not deter the surgeon from submitting the tissues. If the pathological report states that safe margins have not been achieved, the owner should be informed immediately and decisions made on the next sensible stage of the treatment. Combinations of treatments using different surgical techniques, or surgery plus other modalities, such as immunotherapy, radiation, or chemotherapy, improve the chances of a good outcome.

Sharp surgery

Sharp surgical excision of a tumor is clearly the fastest and most convenient method of treatment in most cases. Localized, benign or early localized, malignant tumors may be amenable to surgical excision. For example a squamous cell carcinoma of the tip of the tongue, a gingival fibrosarcoma, or a buccal sarcoid may be treated effectively by surgical excision.

Laser surgery

The increased availability and relatively low price of diode lasers now makes this a realistic option in most practice circumstances. It is still a surgical method and suffers from the same limitations as sharp surgery (Fig. 11.4). The advantages of laser surgery are its accuracy, the relatively bloodless surgical field, and the fact that some extra ‘die-back’ occurs when tissues are cut with a laser; the latter is also something of a disadvantage in that healing is slower, and sutured wounds may break down. Laser surgery also minimizes the risks of tumor seeding into the operative site. This is particularly important in the treatment of sarcoid tumors.

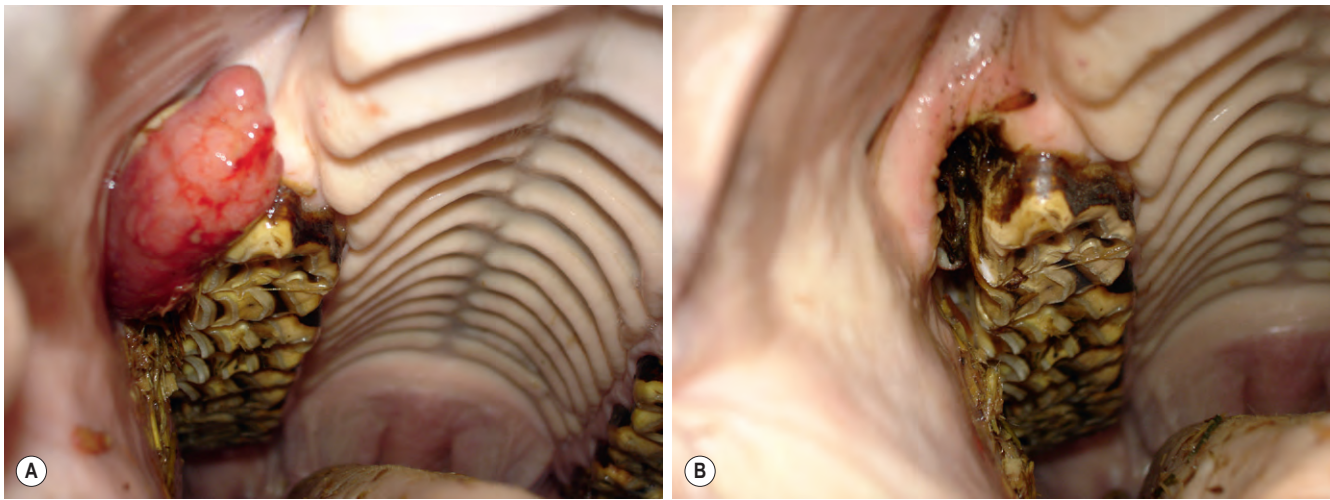


Fig. 11.4 (A) This oral fibroma had caused external cheek swelling and hemoptysis. (B) Following laser surgical excision in the standing sedated horse, the tumor did not reoccur.

Diathermy

This is very similar in use to diode laser surgery. Again, the margins remain relatively bloodless (at least until the surgery has been completed), and tumor seeding of the site is limited.

Cryosurgery

Small, focal, and superficial tumors can be treated by cryonecrosis. Systems using liquid nitrogen are the only ones that are effective in horses; however, the crude application of liquid nitrogen to a tumor mass to induce an uncontrolled freeze is unacceptable. The advantage of cryosurgery is that it is possible to destroy a wider area of tissue and allow a natural demarcation to develop over the following weeks. Cryosurgery is not suitable on its own for larger aggressive tumors since it is almost impossible to define the margin of the 'freeze' without complicated use of thermocouples, and in any case, the oral cavity appears to be much more difficult to freeze effectively than normal skin.

Chemotherapy

The options for chemotherapy in horses are limited to topical and intralesional medication. Usually, the materials are specific antimetabolic or cytotoxic drugs, such as cisplatin (in stable emulsion, wax, or biodegradable bead forms), 5-fluorouracil (in solution, bead, or sponge forms), bleomycin, or mitomycin C in injectable solution. Although these are attractive options because they are logistically simpler and invariably cheaper than other methods, there is little information regarding their use in equine oral neoplasms in particular. Broadly, they have applications in the management of sarcoid, melanoma, and squamous cell carcinoma,²⁰ but more information is being published about their use and applications for other tumor types. As might be expected, the position and size of the specific tumor being treated

limits the opportunities for its use, and where tumors are presented late, the scope for effective treatment remains limited. Electrochemotherapy using electrical energy to increase the permeability of tumor cells to cisplatin (and possibly) 5-fluorouracil has recently been described for the treatment of buccal²¹ sarcoid and there are anecdotal reports of the benefits in squamous cell carcinoma and melanoma treatment also. The advantages of this system include the fact that the current can be restricted to the tumor location, but this method requires repeated general anesthesia. The biodegradable sponge or bead systems appear to be very logical and these may become the preferred practical approach in many circumstances. However, there are no comparative evidence-based studies on these methods to date.

Immunotherapy

Whilst various forms of immunotherapy, ranging from 'autogenous vaccines' (for melanoma) to intralésional BCG protein injections (for sarcoid, in particular), have been suggested to treat equine neoplasms, assessment of their value is limited by the lack of comparative clinical studies. Sarcoid seems to be the most prevalent tumor type that is subjected to this therapy, and there are some reports of its positive effects in certain types of sarcoid.

Radiation therapy

Radiation therapy is the gold standard therapy for most cutaneous and deep-seated malignant tumors in the horse. Radiation is used to eradicate the tumor cells, preferably without affecting the architecture and cellular elements of the adjacent normal tissues. Both gamma and beta radiation are used therapeutically through plesiotherapy, brachytherapy, and teletherapy. Radiation brachytherapy causes no material systemic toxicity and in contrast to surgical methods of treatment, has no anatomical constraints. However, it is seldom available for equine therapy for cost and logistical reasons. The likelihood of a successful outcome with radiation therapy is inversely proportional to the size

of the tumor; this is a common constraint given the late presentation of most cases of equine oral tumors. The prognosis also depends on the tumor type, and its particular growth characteristics and susceptibility to radiation; slowly expanding tumors tend to respond more slowly and less favorably than rapidly dividing ones. For example, squamous cell carcinoma is probably more susceptible to gamma radiation than the fibroblastic sarcoid, and melanomas tend to respond poorly to all types of radiation. However, the same tumor type may respond differently in two different anatomic sites and in different horses, and so variations in 'effective' doses are almost infinite.

Disappointingly, there are few facilities that offer any sort of radiation therapy for horses. This reflects a totally unacceptable lack of interest in cancer medicine in a species that makes an enormous contribution to mankind! However, radiation can be used, and there are cases where interstitial brachytherapy or teletherapy has made a significant difference for oral tumors in particular.

Brachytherapy

Interstitial brachytherapy has considerable advantages in that high doses of radiation can be delivered precisely, safely, and conveniently over a short time without significant risks to the other parts of the body. Radioactive sources are implanted into tissues directly and are left in situ until a precalculated overall dose of radiation is delivered. The dose necessarily varies for the various types of tumor, but little is established about the best options for oral masses. Therapeutic radiation ionizes the DNA in cells within the therapeutic range of the sources but is not discriminatory for tumor cells alone. This means that susceptible normal cells are usually destroyed as well. The most susceptible normal cells in the skin are melanocytes, and so pigmentary changes are common. Iridium-192, gold-198, and iodine-125 are the most common isotopes used in this way. The procedures are all highly specialized, requiring careful dosimetry and specialist facilities both for insertion and hospitalization. The results obtained in 12 cases of oral neoplasia²² suggest that this is a potentially very satisfactory method of treatment. However, there are obvious difficulties relating to the availability and costs of such treatment. Since one of the major constraints on the outcome is the size of the tumor, the costs and the dose required can be reduced significantly by prior surgical debulking of large tumors.

Teletherapy

Teletherapy uses a generated beam of radiation (high energy beta or gamma rays) focused into the tumor mass. The main advantages are that no operator risks are incurred, the dose can be focused accurately, and several sub-lethal rays can be focused into a deep tumor without causing significant damage to the surrounding tissues. Where the beams meet, a radiation 'hot-spot' is produced that receives a lethal radiation dose. The problem is that this method, whilst being the true gold standard, is not available to horses at this time. General anesthesia would be required to allow treatment of most equine oral tumors, and no quantified dosimetry has been calculated for any equine tumor. A few cases of sarcoid,

lymphoma and squamous cell carcinoma of the face and head have been treated successfully in this way.

Other 'treatments'

Cancer always warrants a proper investigation and sensible treatment that has a prospect of helping, and where treatment is impossible an honest and direct opinion should be given to the owner. In spite of the availability of a variety of appropriate treatment options there are still many occasions when useless or even dangerous treatments are inflicted upon horses. Whilst homeopathy, for example, cannot possibly do any good, its main danger lies in the failure to provide effective and timely treatment and in causing unnecessary delays before proper therapy is instigated. This also means that the prognosis is far worse when proper treatment is finally requested and when that fails, the poor outcome is usually taken as indication of the inadequacy of the conventional methods! Since homeopathy has a positive explanation for any of the possible outcomes ranging from success to failure it must be viewed with a considerable degree of skepticism by any scientific mind. In spite of the considerable cost and the lack of any evidence of any efficacy whatsoever, these methods continue to be peddled by people who exploit the ignorant, the vulnerable, the gullible, and the disillusioned!

Tumors of dental-tissue origin (odontogenic tumors)

Tumors in this category are rare, although it has been suggested that they are more common in horses than in other species.¹⁷ Odontogenic tumors are classified according to the inductive effect of one dental tissue on the others.^{18,23} These tumors can be benign or non-metastasizing malignant, with the latter often locally invasive and aggressive in their clinical behavior. As a general rule, dental tumors are best treated by wide surgical removal (to ensure complete ablation of tumor and abnormal tissue) at an early stage in their development when such surgery has a chance of success. In most cases, however, the masses are not recognized sufficiently early, and so local recurrences are common in spite of attempts at wide surgical excision.¹⁹ Most oral bone and dental tumors are benign but can cause serious secondary effects, such as nasal obstruction and dental and facial deformity, resulting in dysmastic weight loss. There are some similar clinical conditions that resemble neoplasia that are in fact simply abnormal tooth formation (Fig. 11.5). An important diagnostic aspect in these cases is that the condition is present from the time of formation of the tooth. However, on presentation they may be very difficult to tell apart. Since the advent of equine dental medicine as a specialty, early recognition of abnormalities and deformities as well as neoplastic dental disorders, has become much more frequent.

Odontogenic tumors are of variable histological appearance and are categorized currently on their morphologic basis²³ (Table 11.1). Their features are summarized in Table 11.2.



Fig. 11.5 This tumor-like mass developed in the incisive gingiva of a 12-year-old gelding. Biopsy was inconclusive, and only after full surgical removal was a diagnosis of an inflammatory reaction possible. Even then there remained some doubt, but as the condition did not recur, the matter was not pursued.

Table 11.1 Equine dental tumors derived from odontogenic epithelium (E) or mesenchyme (M)

Histologic designation	Synonyms
Ameloblastoma (E)	Keratinizing ameloblastoma adamantinoma
Cementoma (M)	
Complex odontoma (E)/(M)	
Cementifying fibroma (M)	
Ameloblastic fibroma (E)/(M)	Ameloblastic fibro-odontoma

Table 11.2 Summary of features of odontogenic tumors based on published characteristics^{20,36}

Tumor type	Age group (yrs)	Clinical behavior	Best treatment option	Prognosis
Ameloblastoma	Wide range	Benign/locally invasive	Surgical excision/ hemimandibulectomy ± radiation	Fair–good; eating difficulties may be severe
Ameloblastic odontoma	<3	Benign/locally invasive	Surgical excision/ hemimandibulectomy ± radiation	Fair–good; eating difficulties may be severe
Cementoma	Onset uncertain	Benign	Surgical removal	Good
Compound odontoma Complex odontoma	<5	Benign malformation	Surgical removal	Fair (if removal feasible)
Cysts/hamartoma	Various	Benign	Surgical removal	Fair (if removal feasible)

Ameloblastoma

Definition

These tumors are derived from odontogenic epithelium. True ameloblastoma produce no inductive changes in the connective tissue and so lack dentin and enamel.

Occurrence

These are most commonly found in the mandibular region (including medulla) of older horses^{24–29} but can involve the maxilla. Several cases have also been reported in young foals.^{30,31}

Clinical features

They may be overtly tooth-like, or contain little or no obvious dental tissue. They often develop a central, cystic region and cause bony/solid swellings and abnormalities in the associated dental arcade (Fig. 11.6). Occasionally, they can present with a discharging sinus on the side of the face. Late presentation shows an advanced and aggressively destructive epithelial tumor with extensive bone loss (Fig. 11.7).

Differential diagnosis

Ossifying fibroma and other tumors of the jaw, such as invasive squamous cell carcinoma and myxomatous tumors,

should also be considered (although the latter tend to be destructive rather than proliferative). Osteosarcoma is singularly rare in the horse. Infections of tooth apices and adjacent bone can be similar, but are associated with extensive necrosis and typical radiographic features often complicated by maxillary reactive bone proliferation with obvious facial swelling. Jaw fractures and other dental abnormalities, including malerupting and supernumerary cheek teeth, should also be considered.

Diagnostic confirmation

Biopsy and radiographic findings are typical but can be similar to other tumor masses. Ameloblastomas usually have a rubbery consistency and have a roughly spherical or multilobular shape with a cystic radiographic appearance (Fig. 11.6B). Odontomas are radiolucent or partially mineralized, with foci of calcified tissue mixed throughout. Even when there is extensive ulceration, there should be little confusion between ameloblastomas and carcinomas or sarcomas, which tend to be much more destructive than tumors of dental origin.

Pathology

Ameloblastoma is characterized grossly by swelling of the affected jaw and osteolytic changes within the jaw (Fig. 11.6C). They can be solid or cystic and are usually discrete. The major characteristic histological feature is the presence of odontogenic epithelium (Fig. 11.6D). If there is

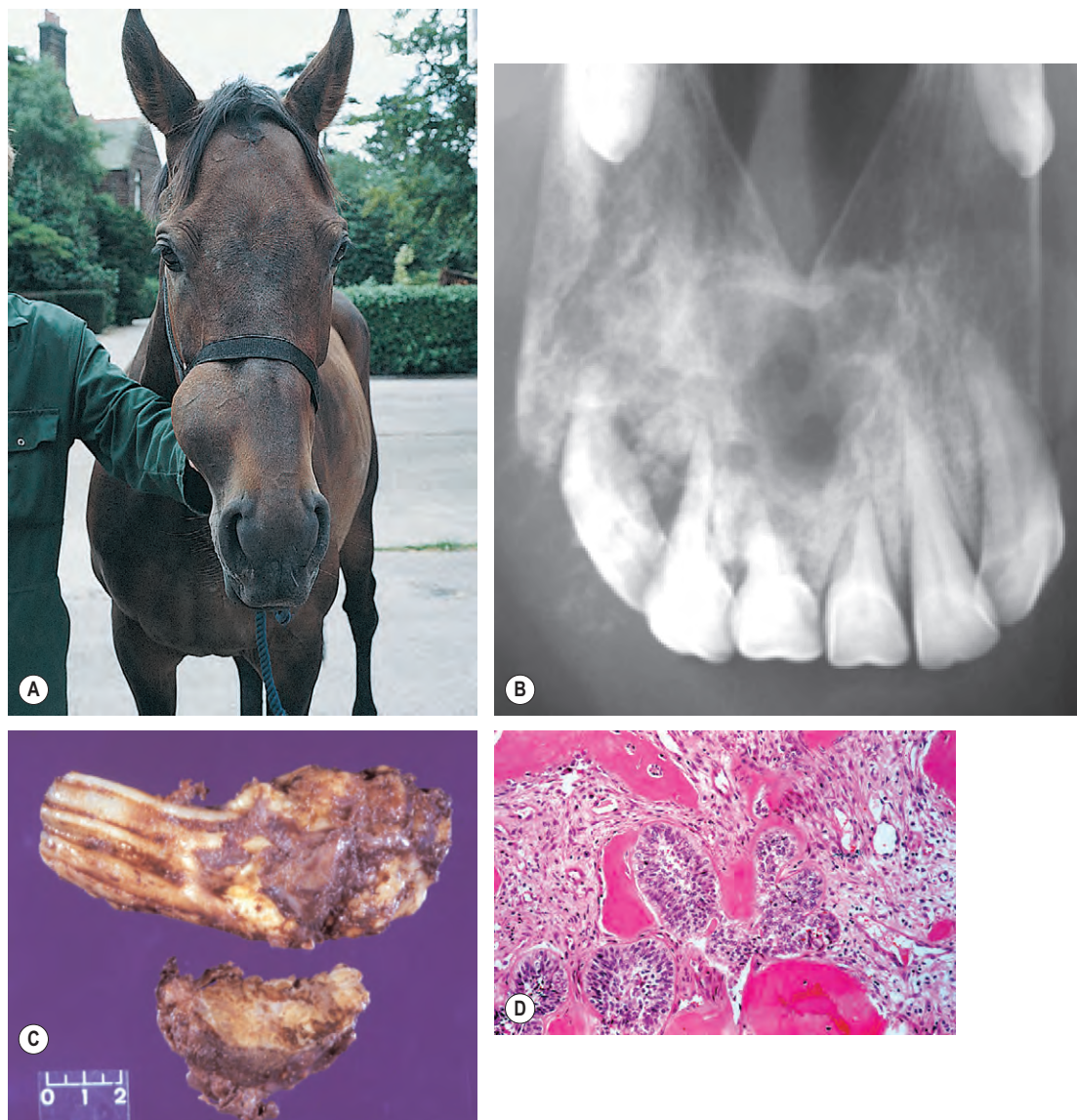


Fig. 11.6 (A) Facial swelling caused by an ameloblastoma. The tissue contained no obvious dental tissue remnants. This differentiates it from an ameloblastic odontoma. (B) Radiographic appearance of an ameloblastoma in a 2-year-old Thoroughbred colt showing the characteristic multiloculated nature with radiodense fragments throughout the mass. Reproduced with the permission of Dr Bruce Bladon. (C) An ameloblastoma excised from a 2-year-old Thoroughbred colt showing the relationship to the tooth and the expansive mass at and around its root. (D) Histologic section of an ameloblastoma showing clusters of orderly ameloblasts separated by connective tissue and spicules of hard dental material.



Fig. 11.7 (A) Massive ameloblastoma is present in the rostral mandible. (B) Boiled out post-mortem specimen showing gross destruction of the rostral mandible caused by an ameloblastoma.

marked epithelial keratin formation, the lesion is termed keratinizing ameloblastoma. The lesion may be well circumscribed, or there may be local infiltration by odontogenic epithelium.

Treatment

Surgical removal can be curative if treatment is initiated early and wide excision can be performed. Horses seem to cope well with rostral hemimandibulectomy and especially so if the mandibular symphysis remains intact. Rostral mandibulectomy can also be successful, but special measures are required to ensure adequate nutritional intake. Radiation therapy is probably the best option and has been used successfully.³¹

However, suitable teletherapy facilities are not generally available, as noted, and so other options are usually sought. Topical chemotherapy is singularly unsuccessful.

Prognosis

The expansile nature of these tumors and their late recognition (particularly in foals and young horses) make the outlook poor. Many horses are euthanased soon after they are diagnosed with the tumor, although the rate of growth may be slow and some useful quality of life may be possible even if surgery is not feasible.

Cementoma

Definition

Cementoma is a rare, benign or reactive tumor derived from mesenchymal tissue and so does not contain epithelial components. It typically occurs in the apical region of the developing tooth. There are few published reports of this tumor, but one such lesion affected an incisor tooth (DCK, unpublished). It is possible that some of the features of this condition could be found in abnormal or supernumerary cheek teeth where extensive distortion of the dental structures by reactive cement deposition is encountered. However, it is often impossible to confirm the diagnosis of cementoma or to differentiate them from dental abnormalities.

Clinical features

The location of these tumors (at the apex of the tooth) makes their early recognition and diagnosis unlikely, and they are only recognized when there is overt jaw swelling (Fig. 11.8). Radiographically, they have a distinctive, very radiodense appearance, and the tissue contains sheets of cementum-like material. Secondary alveolar changes involving either infection or reactive bone proliferation may, however, make them harder to recognize. Alterations in the crown are unusual but make the condition more recognizable clinically.

Pathology

This lesion presents as a mass in the jaw or as a mass that involves the nasal cavity or maxillary sinus. It may be secondary to traumatic tooth fracture, dental impaction, or periodontitis. It is characterized histologically by the

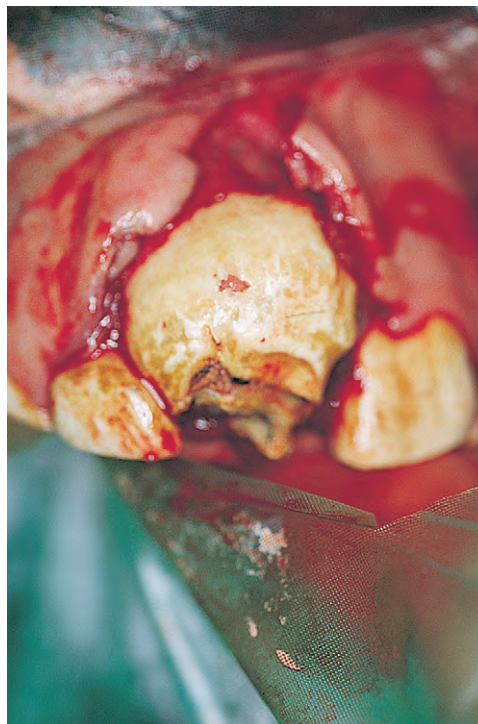


Fig. 11.8 Cementoma of the crown of an incisor tooth in a 3-year-old Hanoverian mare.

presence of mosaic-like, basophilic cement lines, with anchoring of Sharpey's fibers into the cement matrix. With reactive cementoma, there is additional inflammation and fibrosis. Cementifying fibroma is a rare lesion that is analogous to ossifying fibroma, but the tumor matrix includes the complex basophilic lines of typical cementum.

Treatment

Removal of the tooth in its entirety is feasible but may be hindered by the large, cylindrical aggregation of hard tissue at the tooth apex. In some circumstances, it might even be better to accept the condition since it is generally very benign, and its slow onset may enable the horse to adapt well to it.

Prognosis

The lesion is benign and removal is curative. Some horses remain unaffected for many years with the condition being identified incidentally or at post-mortem examination. However, where clinically significant secondary changes occur, the prognosis depends on the possibility of removal of the affected tooth.

Complex/compound odontoma

Definition

A complex (compound) odontoma is an irregular, tumor-like mass of dental tissues in a well-differentiated form. Complex odontoma contains all the elements of a normal tooth, but the structure is chaotic. A compound odontoma is similar, except that the tissue is organized into

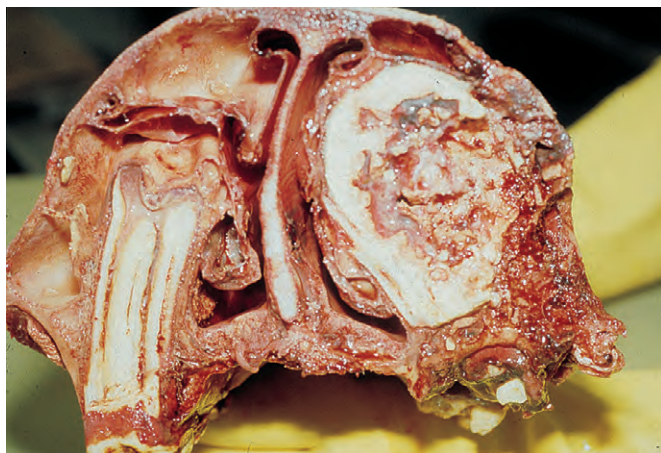


Fig. 11.9 The gross distortion of the maxilla due to a compound odontoma.

recognizable, tooth-like structures (denticles), although they may be grossly distorted. There is some justification for considering some compound odontomas to be hamartomas of dental tissue, rather than true tumors.

Occurrence

Both young and older horses may be affected, with a greater prevalence in younger animals.

Clinical features

Many cases are identified incidentally. Firm, painless swellings over the apical regions of the maxillary cheek teeth or the premaxilla are characteristic.³³ Swelling may not be obvious if the more caudal maxillary cheek teeth are involved as the expansion is contained in the maxillary sinuses (Fig. 11.9). Secondary sinusitis seems to be a rare complication.

Differential diagnosis

Dental infection with new bone formation and lysis. Sinus cysts may be associated with these in some cases.

Diagnostic confirmation

The radiographic appearance is characteristic – multiple, small lobulated masses within a well-defined cyst-like structure at the apex of a maxillary tooth are typical. Radiographic interpretation of the lesion becomes difficult when secondary changes occur in the adjacent teeth and sinuses.

Pathology

Complex odontoma presents as a radiodense calcified lesion within the jaw of young horses. Grossly, they are very hard and difficult to prepare for histological examination. Cut surfaces reveal variegated cementum, dentin, and mineralized enamel (Fig. 11.10).³⁴ The gross features are confirmed histologically, and there can be variable amounts of odontogenic epithelium. In the horse, there is plentiful cementum.

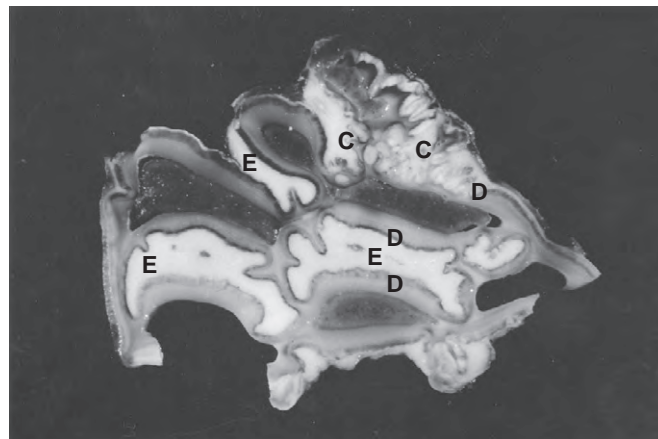


Fig. 11.10 Undecalcified thick section of a complex odontoma in a 2-year-old Morgan colt. Well-differentiated but disorganized components of tooth formation are shown. D, dentin; C, cementum; E, enamel. (Reproduced with the kind permission of Dr R.R. Dubielzig and Iowa State Press.)

Compound odontoma presents as a similar lesion but radiographically shows several abnormal tooth-like structures (denticles) within the mass. Histological features are reminiscent of normal tooth development. In older lesions, epithelial tissue may be sparse.

Treatment

Surgical removal may be feasible and curative. Surgical removal and cryosurgery combined can be used, but some masses require more than one treatment.

Prognosis

Full surgical removal should resolve the problem, but repeated surgery may be needed. There are insufficient reports to establish a definitive prognosis but, the few published cases suggest that the outlook is reasonable or even good.

Incidental tumor-like dental masses

This group includes temporal teratoma – a rare curiosity in the horse, in which dental tissue (which may be instantly recognizable as such) is located at sites away from the jaws (Fig. 11.11). The most common site is in the temporal region where a sinus tract discharges viscous, milky material from a discrete opening on the leading edge of the pinna. The cystic structure may be situated some way from the ear itself but sometimes there is an obvious dental structure located against or attached to the temporal bone of the calvarium. Sometimes the structure has no obvious dental tissue and comprises a smooth, cystic lining lying below the ear. Radiographs are used to establish the presence or absence and the location of any dental tissue.

Pathology

These rare lesions are lined by stratified squamous epithelium and often contain abnormal dental structures.^{35–38} The

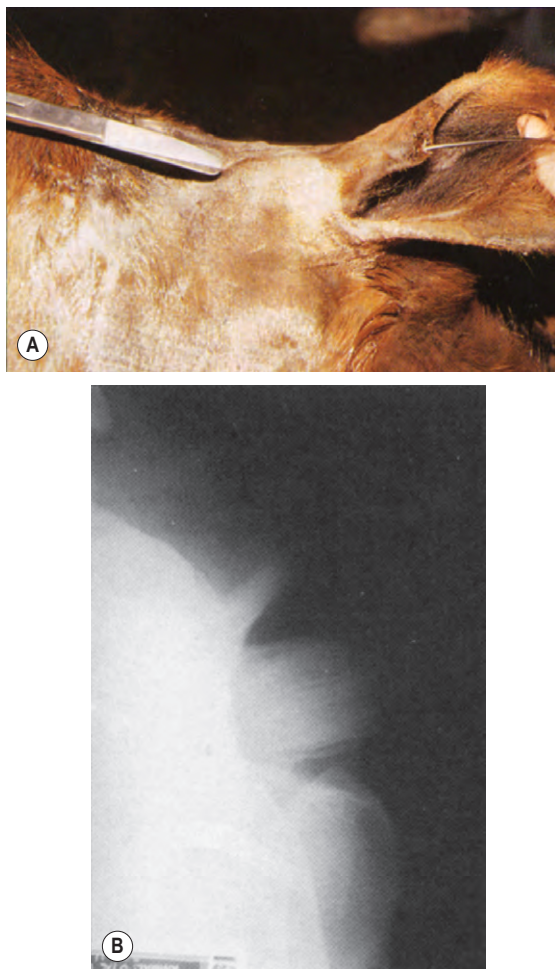


Fig. 11.11 (A) A discharging sinus had been present on the anterior margin of the pinna (where probe is inserted) for 2 years. The tract leads to an obvious solid non-painful mass just rostral to the base of the ear. This is the typical clinical appearance of a dentigerous cyst. (B) Oblique radiograph of the temporal region of the same horse as in (A). An obvious tooth-like structure with an associated 'alveolus' is present and is typical of many cases of dentigerous cysts. In the absence of obvious tooth-like structure, contrast radiography will identify a distinct or occasionally a poorly defined cystic structure at this or a neighboring site.

surgical treatment of temporal teratoma can carry a good prognosis, particularly where the lesion is simply a cystic structure, although every part of the cystic lining must be removed to avoid recurrence. However, where aberrant tooth material is enclosed within a false alveolus protruding into the calvarium (see Fig. 11.11B), surgery becomes much more of a challenge. Such cases must be fully assessed by CT scan, if possible, or at least by radiography (possibly with contrast material introduced via the sinus tract). In some cases, the cyst and the tooth-like structures are not obviously connected. Some cases can justifiably be left alone since the discharging tract is usually a cosmetic and managerial nuisance, rather than being clinically significant.

Tumors of bone (osteogenic tumors)

Osteosarcoma, osteblastoma, chondrosarcoma, and fibrosarcoma have been described as arising in bone in horses.

They are all very rare tumors, but there have been several reports involving the jaws and the mandible in particular, which indicates that this may be a predilection site.⁴⁰ The histological characteristics of bone-derived tumors have been described,⁴¹ and the classification of this group of tumors is based upon these features.

Osteoma

Osteomas, which are extremely rare lesions, are slow-growing, solitary, well-differentiated masses of bone enclosing marrow and fat, and many pathologists regard them as a developmental anomaly or hamartoma, rather than neoplasms. They are reported to occur in all ages of horse, with most being located in the head region, including the mandible, maxillae, and paranasal sinuses. The osteoma may reach a large size and have a distinctive, discrete, radiodense outline. They are benign, but their growth may compromise adjacent tissues, causing disfigurement, obstruction of the nasal passages or interference with mastication and swallowing.

Macroscopically, they consist of dense bone. The histological features are of orderly cancellous bone; the intertrabecular fibrous connective tissue may include adipocytes and hemopoietic cells.

Surgical removal may be feasible, but most are a significant surgical challenge, and the prognosis is very guarded.

Osteosarcoma

Definition

Osteosarcoma is a malignant mesenchymal tumor of bone affecting horses of any age, in which the neoplastic cells produce modified or distinctive osteoid or bone matrix in a haphazard arrangement.

Occurrence

Osteosarcoma is an extremely rare tumor in the horse at any site. However, over 80 % of reported osteosarcomas involve the head, and the majority are reported in the mandible.^{42,43} There is a report of an osteosarcoma in the mandible of a 6-month-old Quarterhorse colt, which suggests that age is probably not a significant factor,⁴⁴ although, typically, younger horses appear to be more prone to oral or dental neoplasia in general than older ones. Trauma is implicated as a risk factor for later osteosarcoma in other species such as the cat, but there is no convincing evidence for this in horses.

Clinical features

The condition is usually presented as a painful, hot, progressive swelling of the mandible with a characteristic 'sun-burst' radiographic appearance of bone lysis and irregular deposition of trabecular reactive new bone⁴⁴ (Fig. 11.12). Pathological fractures can occur in affected bones.

Differential diagnosis

Infection resulting in osteitis or osteomyelitis (particularly with *Actinobacillus* spp.) can be very destructive, and appear

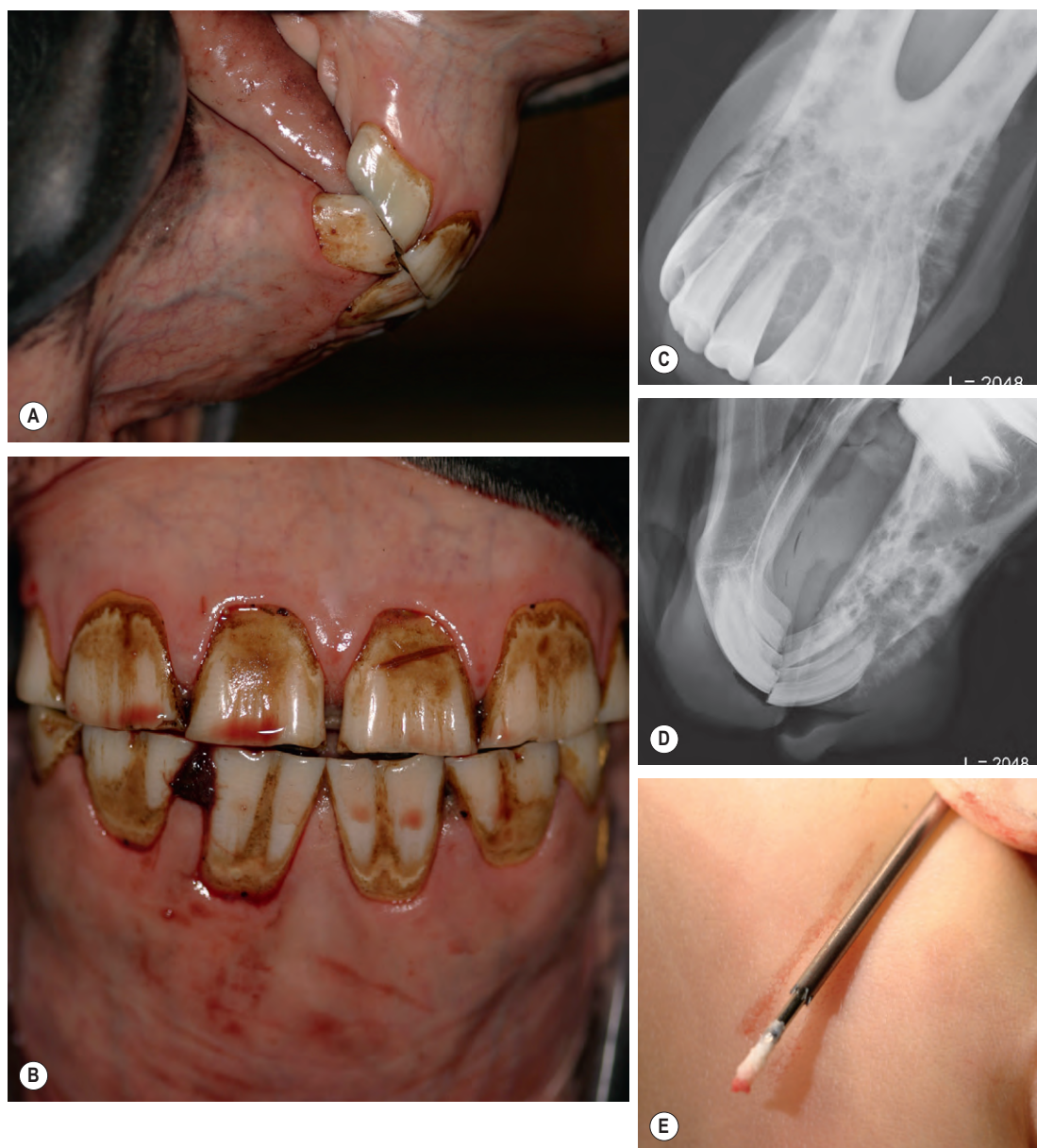


Fig. 11.12 (A) & (B) This 5-year-old Irish Draught mare was presented with a 4-week history of a mandibular swelling, gingival bleeding, weight loss and dysmimesis. The mandibular incisors were palpably loose and the mandible was warm to the touch and mildly painful on palpation. (C) & (D) Lateral and occlusal radiographs gave the suspicion of a neoplastic lesion. (E) A bone biopsy was taken from several sites, and the horse was diagnosed with osteosarcoma.

similar clinically and radiographically to osteosarcoma. Various cystic structures, such as ameloblastoma, ossifying fibroma, and fibrous dysplasia can be clinically similar but usually have characteristic radiographic differences.

Diagnostic confirmation

Their radiographic appearance is highly suggestive, but biopsy provides the only definitive diagnosis. There is a characteristic combination of cortical bone destruction and periosteal new bone formation giving the area a 'sunburst' radiographic appearance.

Bone biopsies of osteosarcoma are sometimes easy to obtain, since the bone is usually softer than normal and the medullary cavity is filled with diagnostically significant

friable pink to white material containing variable amounts of cancellous bone (Fig. 11.12E). It is easy to miss tumor tissue in small bone biopsies, and florid, non-neoplastic reactive bone or fracture callus can easily be mistaken histologically for neoplasia. Multiple biopsies should, therefore, be collected from sites identified by radiography or CT or MR imaging methods, but this is not an easy procedure.

Pathology

Several histological types of osteosarcoma are recognized in other species where its incidence is higher, but this tumor is so rare in horses that it is probably unwise to extrapolate from these findings. The tumor tissue is, however, usually

Table 11.3 Summary of the clinical features of some equine oral soft-tissue tumors

Tumor type	Age group most often involved	Clinical behavior	Treatment options	Prognosis
Squamous cell carcinoma	5–14 y	Benign but can be very destructive	Radiation; cisplatin	Guarded
Sarcoid	All	Locally invasive. Only malignant forms can be very aggressive	Radiation; cisplatin; surgery (nodular type only)	Very guarded
Melanoma	>7 (gray horses)	Low	Benign neglect; cisplatin Cimetidine per os	Fair A few are malignant
Oral papilloma	<2–3 y	Benign	Leave alone; surgical excision	Good but some persist
Epulis	>10 y	Benign	Dental hygiene/descaling	Good
Salivary adenocarcinoma	>10 y	Malignant	Radiation possible	Hopeless
Equine juvenile ossifying fibroma	2 mo–2 y	Benign	Surgical excision	Fair–good
Myxoma/myxosarcoma	n/k	Variable	n/k	Poor–hopeless

n/k = not known/insufficient reports to make a judgment.

not densely cellular with formation of fibrillar stroma, bone or osteoid tissue. The cells have a high mitotic index and an atypical irregular morphology.

Since this tumor is so rare in the horse, the expected histological appearance is a speculative one based on experience of the lesion in other species. Osteosarcomas are characterized by painful bony swellings with variable degrees of bone lysis, tumor bone formation and reactive periosteal bone proliferation. The histological features are of neoplastic osteoblasts with variable numbers of osteoclasts. The extent of formation of tumor osteoid and/or bone is variable. The tumor bone may, therefore, be hard or soft and hemorrhagic.

Treatment

Radiation offers the only hope of success, but the tumors are likely to be locally malignant, and so treatment is usually not contemplated. Euthanasia is the only realistic option.

Prognosis

There are insufficient data for a reliable prognosis. Although metastasis is seldom reported in osteosarcoma at any site in the horse, it is impossible to predict anything about these very rare tumors. Some may progress relatively slowly and are, therefore, at least tolerable for limited periods. However, the highly aggressive nature and rapid course in most cases justify a hopeless prognosis.

Tumors of soft-tissue origin

Soft tissue tumors of the mouth are far more common than those affecting the teeth and facial bones. A wide variety of tumors have been reported, but only a few occur with any regularity. There is generally more information concerning the diagnosis, management, and prognosis for these equine

soft tissue tumors than for calcified tumors. Many individual veterinarians have preferred treatments for most of the common soft tissue tumors, and some report good results while others are less successful with the same methods.

The clinical features of the main equine oral, soft-tissue tumors are summarized in Table 11.3.

Squamous cell carcinoma

Definition

A squamous cell carcinoma is a malignant neoplasm of stratified squamous epithelium that appears to have a predilection for mucosal junctions.

Occurrence

Squamous cell carcinoma (SCC) is probably the commonest oral neoplasm. Although mucocutaneous junctions are commonly affected with SCC outside the mouth, where there is an apparent correlation with non-pigmented skin and possibly with high levels of ultraviolet light, many of the most severe and aggressive SCC tumors occur within the mouth.⁴⁶ The role of ultraviolet light in the pathogenesis of facial and lip carcinoma is uncertain, but the Clydesdale breed and horses with non-pigmented skin of the face and lips are more often affected than other breeds and colors. Putative carcinogens include chronic irritation, such as epulis, foreign body reactions, chronic wounds, and possibly dietary factors. Older horses are more likely to be affected.

There is often a suggestion that the primary tumor develops in the paranasal sinuses or nasal cavity and the destructive tissue involves the hard palate, but it may be difficult to identify whether the primary lesion is in the sinus or the hard palate.⁴⁷ SCC possibly arises in chronically irritated hyperplastic alveolar epithelium in cases of chronic periodontitis.

Clinical features

SSC tumors are characteristically slow growing but occasionally have a more rapid course. They can be proliferative at least initially, but usually become very destructive, ulcerative and infiltrate widely into local tissues of the mouth including the lips, buccal mucosa, hard palate and tongue.⁴⁸ Early lesions may simply resemble a non-healing wound but more advanced, destructive carcinoma lesions have a characteristic foul odour.

Metastases to local lymph nodes can occur, although the general sentiment is that they do not do so commonly.⁴⁹ In theory, they may disseminate to the lungs and elsewhere. However, this behavior is rare in oral forms of SCC.⁵⁰

Oral SCC may involve the lips (Fig. 11.13A), hard palate⁵¹ (Figs 11.13B,C), tongue^{51,52} (Figs 11.13D,E) or oral mucosa (Fig. 11.13F). It is also quite common for oral SCC to invade the nasal cavity and the paranasal sinuses (often to the point of gross distortion or obstruction to airflow).⁵³ Some SCCs

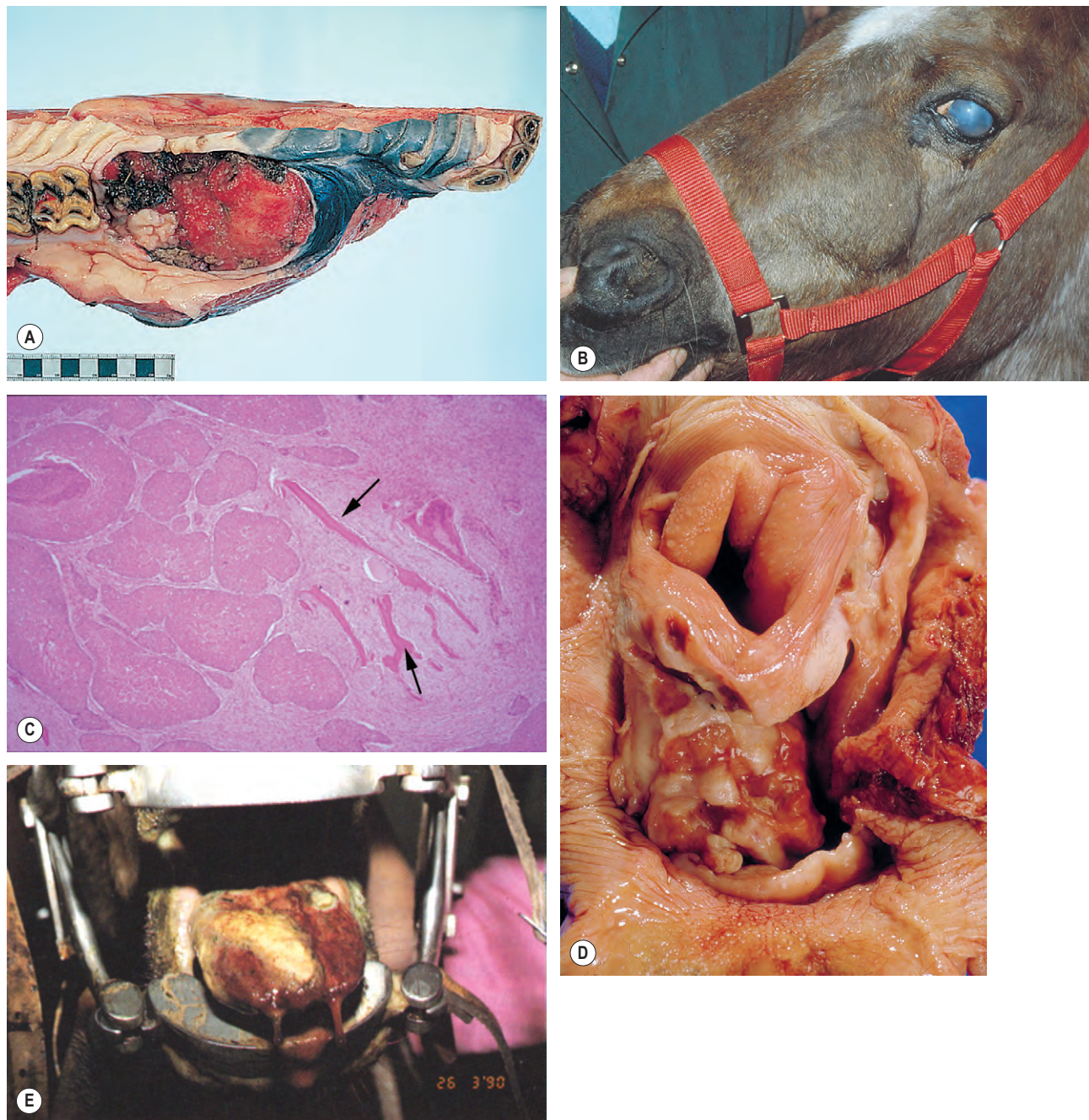


Fig. 11.13 (A) A destructive carcinoma on the lip of a 23-year-old pony gelding. Note the extensive tissue destruction and the loss of the maxillary teeth. Treatment with intralesional cisplatin and topical 5-fluorouracil was not effective. (B) Facial distortion due to nasopalatine squamous cell carcinoma in a 12-year-old pony gelding. (C) A histologic section of the endonasal carcinoma shown in (B). Solid cords of squamous carcinoma are surrounded by fibrous stroma and trabeculae of non-neoplastic reactive bone (arrows). (D) Squamous cell carcinoma of the pharynx, which was identified some 3 months after a lesion had been detected in the hard palate. It is possible that this developed independently or that it was an extension of the earlier lesion. (E) Carcinoma of the free portion of the tongue. The local lymph node was enlarged (see J); slide courtesy of Dr R.R. Pascoe.

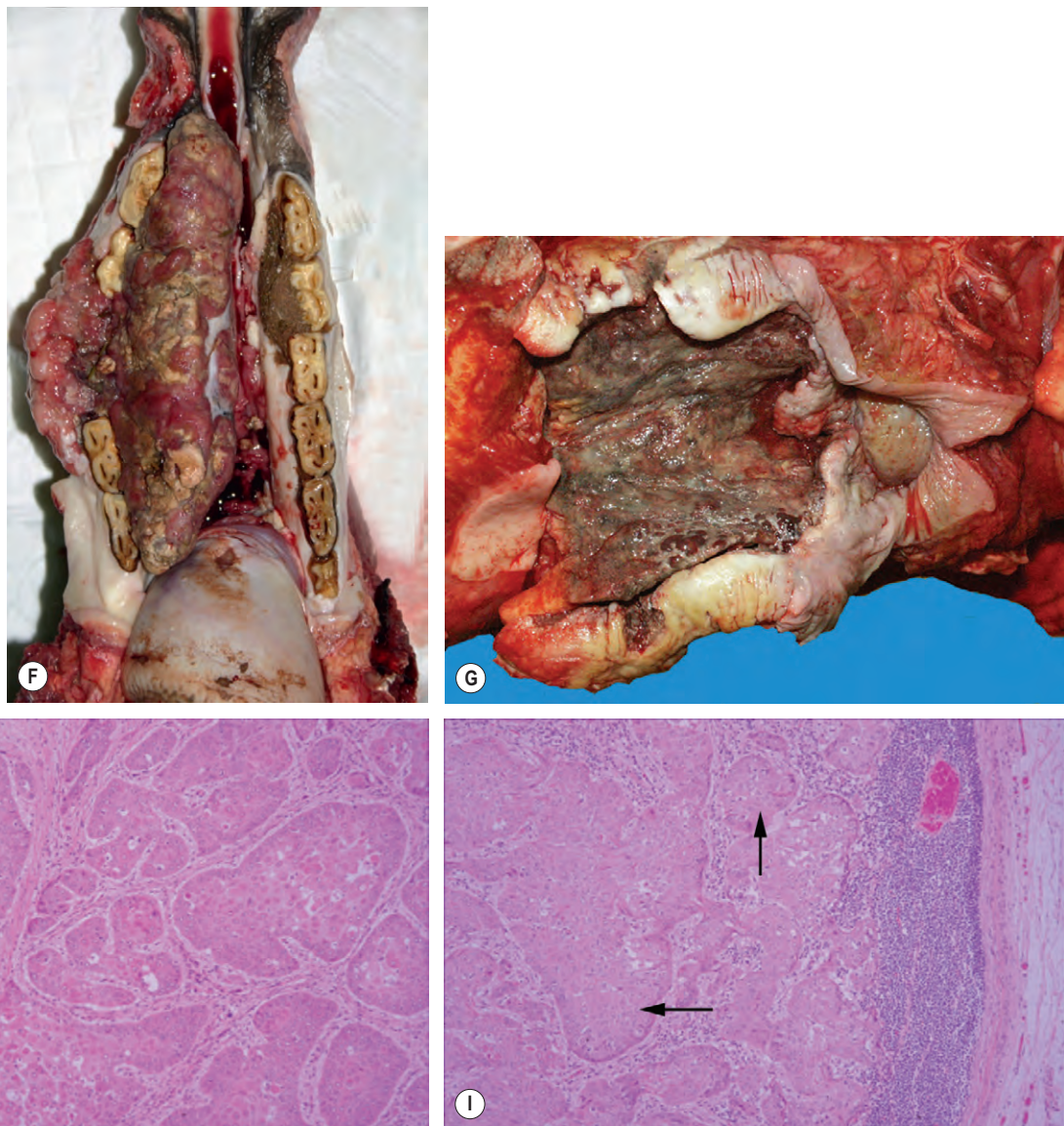


Fig. 11.13 continued (F) This highly destructive oral carcinoma developed in a 4-year-old Warmblood. It involved the maxillary bone and resulted in dental problems also. (Courtesy of Chris Louf.) (G) This horse was presented with weight loss and dysphagia. The highly destructive oral and invasive carcinoma was not visible endoscopically from the pharynx and was only seen with difficulty during an oral examination. (H) Photomicrograph of cords of solid squamous cell carcinoma with deep invasion of the tongue. (I) Metastasis of squamous cell carcinoma to regional lymph node showing cords of tumor cells (arrows) beneath cortical lymphoid tissue.

involve the base of the tongue (Fig. 11.13E) and pharynx (Fig. 11.13G) and can physically affect their function. Where the nasal cavity and paranasal sinuses are involved, there may be altered airflow (or even complete obstruction of the ipsilateral nostril). Horses with pharyngeal and lingual SCCs may present with dysphagia of progressive, insidious onset. In all cases, weight loss and poor general health are common.

More extensive spread may involve the orbit and the cranial cavity with secondary involvement, respectively, of the eye or even rostral brain when the cribriform plate is eroded by tumor. It is also quite common for nasal SCC to invade the hard palate, forming an oronasal fistula. In all cases, there may be extensive soft-tissue disruption and consequent loosening/shedding of the teeth.

The location of SCC means that tumors are frequently detected late when a large invasive mass may already be

present projecting from the gum or hard palate as a grayish, ulcerated and bleeding mass. Where the tumor surrounds a tooth, this may become dislodged, and in almost all cases there is a fetid odor from the mouth. Involvement of the lips and gums is usually clinically obvious; early tumors are often identified incidentally during routine dental procedures.

Differential diagnosis

The differential diagnosis includes other proliferative and invasive soft tissue lesions of the lips, including equine sarcoid, hemangiosarcoma, basal cell carcinoma, and myxomatous tumors. Non-healing oral wounds may be confused with early cases, and carcinomatous changes may be a cause of non-healing.

Diagnostic confirmation

Biopsy is characteristic (Figs 11.13H,I). The pathologist should try to classify the degree of differentiation of the cells; highly differentiated carcinomas are far less dangerous than the undifferentiated ones. Biopsy sites should be carefully chosen to reflect the main carcinoma, with inclusion of a marginal zone as well. Punch or wedge biopsy sites should not be scrubbed or even washed before collection, and the biopsy site should not be sutured afterwards since wound dehiscence is almost certain. Fine needle aspirates and impression smears can be used but may be misleading, since they often consist mainly of stroma and inflammatory cells.

Radiographic examinations can be used to identify masses in the sinuses and the extent of bone destruction produced by invading carcinoma.

Pathology

Histologically, the tumor has distinctive characteristics with irregular cords of downward-invading neoplastic keratinocytes. (Figs 11.13H,I). A SCC characteristically has large amounts of non-neoplastic fibrous stroma in which inflammatory cells are plentiful. The abundant stroma results in a lesion that is characteristically tough or scirrhous when palpated or excised. The accumulation of variable amounts of keratin produces 'keratin pearls' in well differentiated tumors that can be used to define the likely malignancy of the lesion. Poorly differentiated carcinoma shows a more anaplastic cell structure, higher rates of division (high mitotic index), and much less keratin and, therefore, can closely resemble aggressive myxosarcoma. SCC is one of the better defined equine oral neoplasms.

Treatment

While surgical excision of oral SCC lesions has been reported to be successful,⁵⁴ this treatment can be very difficult and in some sites is clearly impossible. There is a very high rate of recurrence following such surgery. Small discrete tumors may, however, be amenable to surgical removal if detected early (Fig. 11.14), and extensive excision involving hemimandibulectomy, such as has been described for other tumors of the jaw, may also possibly remove the tumor but may leave unacceptable cosmetic or functional deficits.

Squamous cell carcinoma appears to be relatively sensitive to gamma radiation, and this therapy offers the best prognosis, with a reasonably high success rate (DCK, unpublished observations). Teletherapy is logical and can be finely controlled, but repeated fractionated doses need to be used, and the horse, therefore, needs repeated general anesthesia. The number of centers where this can be performed is very small, and the procedure is necessarily very expensive. The much simpler 192-iridium interstitial brachytherapy using linear platinum-sheathed sources has been used to good effect (DCK, unpublished observations). There are serious logistic and human health risks involved with the procedure, however, and limitations on the size and location of the tumors that can be treated. Placement of the radiation source within the highly mobile tissues of the mouth carries serious dangers if the horse were to dislodge the wires and swallow them.



Fig. 11.14 A small hemorrhagic and destructive lesion was noted on the tongue of this 22-year-old gelding. Biopsy confirmed it to be squamous cell carcinoma, and surgical excision was performed with a safe margin of excision.

Recently, cisplatin, 5-fluorouracil, and mitomycin C have been used in various intralesional or topical formulations for treatment of cutaneous and other equine carcinomas. Some SCCs respond well to intralesional cisplatin,* either in water-soluble form with frequently repeated injections, as an emulsion of the solution, containing at least 1 mg/ml with an equal volume of sesame or almond oil,⁵⁵ or in biodegradable bead or pellet forms. The use of the above drugs in treating oral SCC has apparently not been reported, but use of all these materials carries operator safety risks. And as such, their use should probably be restricted to specialist oncology centers. There is no justification in taking human health risks through their use by untrained personnel.

The response of equine SCCs to immunomodulation using mycobacterial protein materials, such as *Bacillus Calmette-Guérin* (BCG), is disappointing in horses when compared to treatment of squamous cell carcinoma in other species, such as cattle (DCK, unpublished observations). Treatment of labial SCC with 5 % fluorouracil cream applied topically has been shown to resolve some cases and improve others.⁵⁷ It is, however, a very useful adjunct to other forms of treatment and may be particularly applicable to small, ulcerated, buccal or lip lesions.

Prognosis

The tumors are always locally invasive but usually slow to metastasize, so while the clinical prognosis is inevitably poor, many cases can survive long periods even with quite extensive oral involvement. Oral SCC is a low-grade invasive tumor that tends not to metastasize beyond the local lymph node. However, it is probably unwise to assume that this will be the case in all affected patients. Secondary complications such as facial or oral distortion and destruction, dysphagia, loosening of teeth, and nasal obstruction inevitably suggest a poorer prognosis.

*cis-diamminedichloroplatinum, or cis-DDP, cis-platinum.

Sarcoid

The equine sarcoid is the commonest cutaneous fibroblastic tumor of horses. It commonly involves the cheeks and lips.^{58,59} The term sarcoid is used clinically to describe a spectrum of cutaneous tumors that variously involve connective tissue and epithelium with a range of clinical behavior.⁶⁰ There are usually two distinct forms that affect the mouth itself (as opposed to the skin of the lips and cheeks). The nodular form remains subcutaneous, and is most often located at the angle (commissure) of the mouth or the cheeks and may extend into the mouth (Fig. 11.15A). The verrucose form often involves the perioral skin. In the perioral skin and the tissues of the cheeks, in particular, it often has a highly invasive behavior, then being classified as malignant sarcoid;⁶⁰ it can also ulcerate into the mouth.

Clinical features

Intracutaneous or subcutaneous nodules on the cheek or within the lips having an ulcerated surface are the commonest oral manifestation of sarcoid (Figs 11.15B,C). The nodules frequently ulcerate either on the cutaneous surface or into the mouth. The verrucose form is also a common type in the perioral skin but does not often involve the oral mucosa; however, where the lesions are mixed, a deeper component can be expected and should be sought carefully. Combinations of nodules within the skin and cutaneous involvement of verrucose sarcoid are also common. Nodules may extend through the cheek musculature into the oral mucosa. The fibroblastic forms also occur in the perioral tissues and appear as a fleshy, ulcerated mass of friable and easily traumatized tissue that is very similar to granulation tissue; this form often develops following trauma or failed/partial treatment attempts. The malignant form usually comprises various combinations of the sarcoid types but is highly invasive and nodules may be linked by cords of sarcoid tissue (Fig. 11.15D).

Primary sarcoid has not been reported on the tongue, gingiva or palate.

Differential diagnosis

The equine sarcoid can resemble some forms of viral papilloma, and the nodular forms may be also mistaken clinically for melanoma and mastocytoma. In addition, the fibroblastic and nodular forms may resemble oral fibroma, inflammatory nodules (e.g., foreign body and parasitic granuloma) and granulation tissue arising from any cause.

Diagnosis

Usually an intuitive tentative clinical diagnosis can be made. Horses with a single sarcoid lesion located in the mouth without any other lesion are very unusual. Horses that have the characteristic features and show lesions at other sites can usually be assumed to have sarcoid lesions.

Biopsy is not usually recommended because there are recognized dangers with biopsy of sarcoids.⁶² However, the histological features are characteristic and provided that a suitable contingency plan for treatment is ready prior to the results of biopsy, then it can be a logical diagnostic step.

Pathology

The clinical term 'sarcoid' encompasses a histological spectrum of fibroblastic tumors that may be accompanied by a variable epithelial component. The fibromatous variant is grossly well circumscribed, solitary or multiple, with a tough, pale, fibrous cut surface. Adjacent epidermis is often attenuated and may be intact or ulcerated. Most of the lesion consists of randomly arranged, well-differentiated fibroblasts with plentiful collagen. The malignant variant has ill-defined margins; adjacent epithelium may be ulcerated or intact. Histological features are of randomly arranged, activated fibroblasts that form interlacing bundles and whorls. Individual tumor cells have degrees of anisokaryosis, and mitoses may be plentiful. At the histological level, it may be difficult to discern the limits of the tumor, especially in small tissue samples. The verrucose sarcoid has histological features similar to those in the malignant form and is usually associated with marked pseudoepitheliomatous epidermal hyperplasia (Fig. 11.15E).

Treatment

The options are limited. In some cases, the lesions can justifiably be left alone in view of the risks of exacerbation by incomplete excision. However, inadvertent trauma can also result in severe deterioration, and so early treatment may be strongly recommended in most cases.

Treatment of buccal forms of the disease is notoriously difficult, with radiation, cryosurgery, hyperthermia, laser excision, and intralesional cisplatin carrying some chance of success. Referral to a specialist center is probably justified simply on the grounds that failure of a treatment may result in significant exacerbation of the lesion.

The best treatment is undoubtedly with radiation either as brachytherapy using interstitial linear or pelleted radioisotopes with a gamma emission capability. Radiation has a cure rate of over 95%, and the cosmetic results of this method are impressive. The most frequent isotopes used include iridium-192 and gold-198. The former is presented in linear sources, sheathed with platinum that renders the isotope effectively a total gamma emitter. Gold-198 is used as pellets and has a very short half-life (48 hours) and so this is logistically easier to handle (the sources do not need to be removed) but clearly this method carries much higher operator risks than the lower emissions over a longer period characteristic of iridium. Linear iridium sources are left in situ for the calculated period to deliver the required radiation dose and are then removed (Fig. 11.15F). During the treatment time, the horse must be confined within an approved radiation unit. Complications involving wire displacement and injury or colic during the treatment period can add considerably to the logistic problems. Teletherapy is an ideal method of treatment, but there currently are very few facilities for this treatment.

Other treatments all carry a worse prognosis, with surgery being the most difficult. Intralesional cisplatin using stable emulsions with sesame oil has recently gained some reputation,⁶³ but the method carries very serious carcinogenic risks for operators and handlers alike. Biodegradable beads containing cisplatin (Matrix II, Royer Inc, USA) or sponges with 5-fluorouracil have been used to generally good effect but correct placement is critical, and retention of beads or



Fig. 11.15 (A) This locally invasive sarcoid also involved the buccal surface of the cheek. (B) A localized ulcerated nodular sarcoid. (C) A mixed sarcoid with verrucose and ulcerated nodular components. (D) A locally invasive malignant sarcoid in the cheek with extensive deep involvement of the muscles and oral mucosa. (E) Histologic section of verrucose sarcoid showing a bulging exophytic lesion with pseudoepitheliomatous hyperplasia of the epidermis and diffuse subepithelial fibroblastic proliferation. (F) Linear iridium-192 interstitial brachytherapy was successfully used to treat an invasive sarcoid in the cheek.

sponges is sometimes a problem. Cisplatin use should be restricted to specialist institutes where facilities for fecal and urine disposal ensure that risks to people are minimized. The risks with the bead systems are markedly reduced.

Topical cytotoxic chemicals, such as 5-fluorouracil, imiquimod (Aldara, Graceway Pharmaceuticals, LLC Bristol, UK), and Xterra (20% zinc chloride and *Sanguinaria canadensis* root extract paste) have also been used with variable results. They all require repeated applications, and penetration of lesions is difficult, so failures are common. Scarring is a major hazard particularly if the cheeks are involved and functional difficulties can arise.

Intralesional immune 'stimulants', such as mycobacterial cell wall extracts or BCG, can be effective in some nodular or fibroblastic forms, but the prognosis is far worse than the corresponding results from treatment of periocular sarcoids of the same type.⁶³ Treatment is tumor-volume related, and so large lesions require more BCG material and, of course, each individual lesion requires its own injections. Repeated injections are invariably required, and each one carries the risks of causing anaphylaxis. The possibility of anaphylactic reactions can be reduced (but probably not eliminated) by premedication with flunixin meglumine and dexamethasone intravenously some 15–30 minutes before the procedure is carried out. Ensuring that true intralesional injection has occurred can also reduce these risks.

Prognosis

The prognosis for any sarcoid treatment is very guarded. Recurrences are common, and new lesions can also develop in many sites. While the malignant form is less common than the other variants, it carries a very poor prognosis. The cheek area seems prone to the malignant form. The prognosis for oral or facial sarcoids is also related to the loss of effective work use as a result of interference with tack. Lesions and scarring as a direct result of treatments at the angle of the mouth or in the cheeks can adversely affect the use of bits and harness. Repeated trauma from harness results in continued exacerbation, and so the tumor and the horse become increasingly difficult to manage.

Melanoma

These are tumors of melanocytes occurring in the skin and in other organs (including the mouth and cheeks). The nomenclature of melanocytic masses in the horse is confused and contradictory. There is a spectrum of benign and malignant tumors involving melanocytic cells that are predominantly encountered in gray horses – indeed most gray horses over 5–8 years old have melanomas at some site. Rarely, horses of other colors are also affected. The lips are a relatively common site, but tumors in the cheeks (masseter muscles), gingivae, and tongue may occur.

There is a strong tendency for melanoma to develop in the parotid salivary glands and associated lymph nodes. Tumor development in these sites is usually obvious on clinical inspection. It is not easy to characterize the degree of malignancy in melanomas without resort to biopsy, and even histology may not always provide a firm prognosis. The large majority of melanomas are benign, but some have an aggressive appearance and aggressive growth rate; these usually

have a correspondingly aggressive histopathological appearance. Generally it is accepted that small, early lesions are benign, but that, with time, most become more malignant (whether or not they invade locally or metastasize to remote sites).

Clinical features

Oral melanomas are usually benign and expand slowly but even histologically benign variants can reach considerable size. Surprisingly, tumors on the lips (Fig. 11.16A) and gingivae are often only noticed when they are large. They usually do not cause systemic effects (unrelated melanomas may, however, develop simultaneously in other organs). Extensive lesions can develop in the parotid and pharyngeal lymph nodes and may extend into the parotid salivary gland either directly or by contiguous spread (Fig. 11.16B).

Melanomas affecting the masseter muscle and those that ulcerate into the mouth usually affect mastication, even causing weight loss and dysphagia. In spite of the large size of some of these lesions, the clinical effects are usually minimal and relate simply to their space-occupying nature (Fig. 11.17).



Fig. 11.16 (A) A large melanoma in the lip of an aged gray horse. The lesions expanded slowly but the horse remained symptom-free for years in spite of superficial ulceration. (B) Salivary gland melanoma.

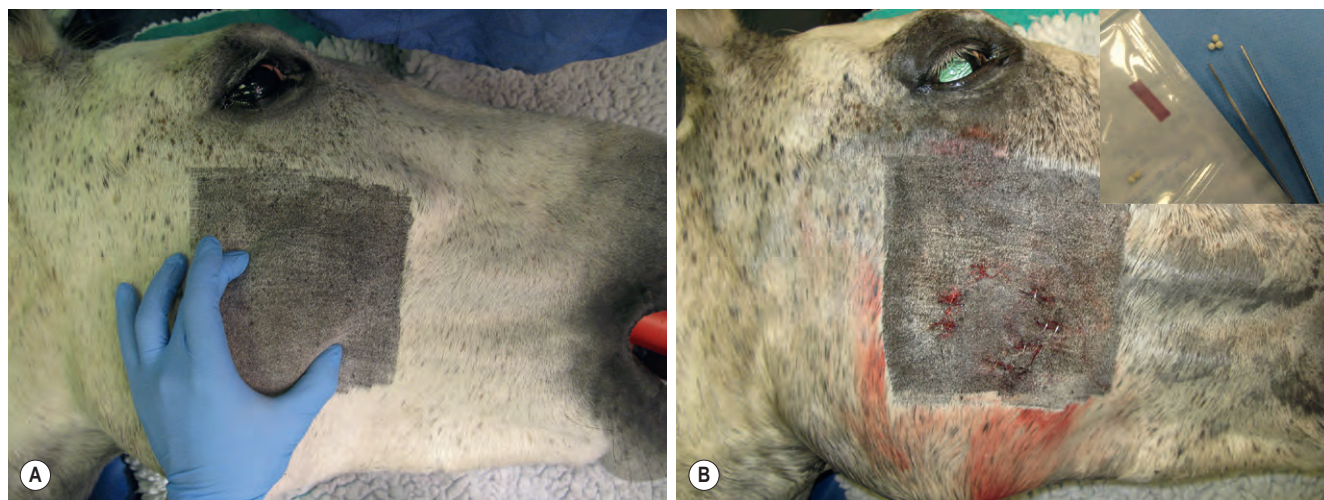


Fig. 11.17 (A) This 9-year-old gelding was presented with weight loss and dysmiasis. The mass in the right masseter muscle, and a similar mass in the left masseter muscle were palpably obvious. (B) Cisplatin biodegradable beads (Matrix II Royer Inc USA) were implanted into the lesion with moderate improvement over 6 months. A second implantation was performed with only a modest further improvement. Insert: biodegradable cisplatin impregnated beads.

Differential diagnosis

Equine sarcoid and mast cell tumors should be considered in the differential diagnosis of lesions that develop in haired skin adjacent to the lips. Parasitic and foreign body granulomas and oral penetration-induced abscesses or granuloma have a similar clinical appearance.

Diagnostic confirmation

The diagnosis of melanoma is easy to establish from clinical features and, if necessary, by use of a fine-needle aspiration or hollow-needle biopsy.

Pathology

Melanomas are bulging, well-circumscribed, gray-black masses that compress adjacent soft tissues, sometimes producing ulceration of the compromised surfaces. Cut surfaces of the tumor are usually glistening, firm, and uniformly black. Occasional lesions may be less homogeneous, less pigmented, or even amelanotic.

Most equine melanomas are characterized histologically by the presence of myriad round-to-oval cells with plentiful, densely pigmented cytoplasm. Two distinct types of cells constitute the tumor:

1. Melanin-producing cells (melanocytes)
2. Macrophages that contain phagocytosed melanin (melanophages).

Pigmented tumor cells may extend into adjacent soft tissues but this is not a reliable histological criterion of malignant behavior. Most tumor sections have to be bleached so that the underlying cytological features can be assessed. Nuclei are usually solitary with a large nucleolus and coarse nuclear chromatin. Mitoses are usually sparse.

There are occasional melanomas with clinical features of malignancy (invasion and metastatic spread); these have corresponding histological features of anisocytosis and anisokaryosis, with plentiful mitoses and variable

cytoplasmic pigmentation. The diagnosis of such less well-differentiated melanoma may be clarified by the use of immunostaining against cell markers, such as Melan A and S100.⁶⁵

Treatment

Many melanomas are left alone without any significant problem apart from the cosmetic aspects. For lip melanomas, surgical excision is sometimes feasible, especially in early cases, and is then usually effective, provided that a surgical margin can be achieved. Regrowth at the site can be a problem because during surgery minute tumors may be seen in the locality, and it is almost inevitable that some of these will be left to develop later. Often, however, by the time functional defects are present, surgical treatment options are very limited. This is complicated by the long-term 'conventional wisdom' that melanomas should be left alone and that there is a risk of metastatic dissemination if surgery is performed. The reality is that pathologic descriptions confirm that very small lesions are very benign and so are a reasonable surgical option. In contrast, advanced lesions often have a malignant histological appearance, and so, at this stage, the risks are far higher. There is some justification, therefore, in the concept that small lesions in accessible sites should be removed as soon as feasible so that at least these particular ones will not become a significant clinical problem and will not become malignant!

Prolonged daily oral administration of cimetidine at doses of 7.5–15.0 mg/kg bodyweight has been suggested as being effective, but the results are not convincing in many cases.^{66,67} Treatment of single or few oral tumors on their own probably does not warrant this approach.

The use of repeated intralesional cisplatin either in stable emulsion with sesame oil and water, or more sensibly in biodegradable beads (Matrix II, Royer Inc, USA), may bring some improvements in some lesions (Figs. 11.17A,B), but complete cures are most unlikely. Radiation therapy is not usually effective against melanoma.

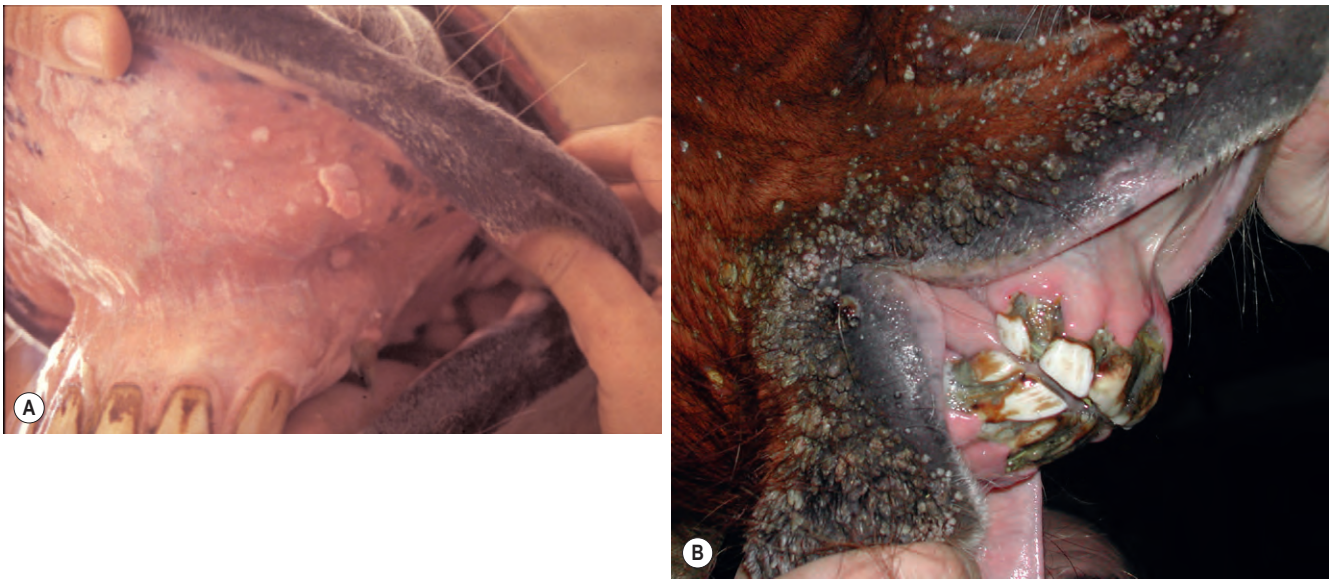


Fig. 11.18 (A) Oral papilloma lesions in an aged horse. (Slide courtesy of Dr Marianne Sloet.) (B) This young horse developed severe papillomatosis of the perioral skin and at the same time showed marked periodontal disease. It was severely immunocompromised by an extensive, multicentric lymphosarcoma.

Prognosis

The prognosis necessarily depends on the location, the particular pathological characteristics and the extent of secondary effects. The prognosis is usually relatively favorable as the majority have no metastatic tendency, but occasionally tumors are locally invasive, and others are very aggressive with extensive metastatic spread and serious secondary effects. As might be expected, older lesions tend to be more malignant, at least in histological character and possibly clinical behavior.

Oral papilloma

Viral papilloma is a relatively common occurrence on the skin of the mouth and lips and, in some cases, they can extend into the oral cavity. Host-specific equine papilloma viruses are the causative virus and usually affect horses in their first year or two of life. Less commonly, they affect older horses and particularly those that have an immunocompromising disorder, such as pituitary pars intermedia dysfunction (PPID/ equine Cushing's disease).

Clinical features

Typically, papillomata appear as single or multiple, discrete or coalescing, verrucose, gray-pink papules around the mouth and, occasionally, on the mucosa of the mouth (Fig. 11.18A). They seldom ulcerate unless they are traumatized. A few cases have lesions restricted to the oral mucosa, and it is not known if these reflect a different manifestation of the same infection. In a few cases, there may be a severe oral infection, and in these cases it is likely that some immunocompromising state exists (Fig. 11.18B).

Differential diagnosis

Viral papilloma can be mistaken for some forms of the equine sarcoid, but as the latter seldom occur in the

verrucous form in the mouth, differentiation should be simple. 'Skin tags' also occasionally develop in the mouth.

Diagnosis

The diagnosis is usually simply based on epidemiology and clinical appearance. Biopsy is characteristic, and most lesions resolve with age, although they may be very persistent in older horses.

Pathology

Papillomas are characteristic exophytic verrucose lesions that may be superficially ulcerated and inflamed. Histological examination reveals filiform fronds of hyperplastic epithelium on fibrovascular cores that often contain plentiful lymphocytes and plasma cells. Intranuclear inclusions may be plentiful or sparse.

Treatment

Most papillomas resolve spontaneously over some months, but individual lesions may persist, often for many years. Therapeutic measures used have included autogenous vaccines prepared from surgically excised lesions and various topical chemicals, including podophyllin and formalin gels. Many of these treatments are impractical on intra-oral lesions and, in those circumstances, troublesome papillomata can be removed surgically or with cryonecrosis.

Prognosis

The prognosis is excellent. The majority resolve spontaneously, and those that do not have no apparent harmful effect on the horse.

Epulis

The term epulis is a clinical description of a smooth gingival nodule and can encompass different types of lesion, such as



Fig. 11.19 (A) Benign, gingival hyperplasia epulis in an aged horse. The lesions were noted incidentally and were symptom-free. (B) Small epulis-like gingival proliferations are present around the base of the upper and lower canine teeth (arrows). After removal of the calculus these inflammatory lesions disappeared.

hyperplasia, granuloma, or even neoplasia. These tumor-like masses develop from the fibrous tissue of the gingiva and are often, but not always, associated with the accumulation of dental calculus caused by chronic local irritation due to persistent periodontal infection. In horses, they are much less common than in some other species, such as the dog and cat, and seldom reach significant proportions (Fig.11.19A).

Clinical features

Usually epulis appears as a benign expansion of the gingival epithelium resulting in thickening and prominence of the gingiva particularly evident at the gingival margin where it may be focally raised (Fig.11.19B). A few cases develop ulcerated proliferating masses at the site that can be much more like a true neoplasm, and these may closely resemble oral fibroma.

Differential diagnosis

Viral papilloma, sarcoid, and the proliferative forms of squamous cell carcinoma are the main differential diagnoses; all are easily identified histologically after surgical removal.

Diagnosis

The condition is distinctive clinically, but refinement of the clinical diagnosis depends on histological examination of resected epulides or a biopsy. Biopsy may, however, be misleading if granulation tissue is present, and in any case they may still be very similar histologically. The main differential diagnoses are, however, usually easily identified histologically.

Pathology

There is poor histological characterization of the epulides, probably because they are easily recognized and are seldom treated: few are examined histologically.

Treatment

Removal of the causative factors usually results in complete resolution. Many cases resolve spontaneously after any dental calculus or damaged dental or adjacent soft-tissue structures are removed. Recurrence of both calculus and epulis should encourage a careful assessment of the whole horse in case there is any systemic disease present.

Prognosis

The prognosis is excellent. There are no reports that they are precursors to more malignant tumors, such as squamous cell carcinoma, but one case developed a locally aggressive carcinoma some years after a benign epulis was removed from the base of a canine tooth (DCK, unpublished observation). It is probably unwise to draw any causative inference from this single case.

Oral fibroma

Definition

This is a well defined exophytic fibroma that occurs with some regularity in the horse. The clinical similarity of this tumor with sarcoid and epulis can be diagnostically confusing. Possible causes include persistent local inflammation due to periodontal infection or calculus build-up, or foreign body reactions (similar to epulis). However, many of these lesions occur in otherwise normal mouths. Most are slow-growing and symptomless; almost all early cases are detected incidentally during routine dental examinations. The benign forms may progress to invasive fibrosarcoma.

Occurrence

There are few reported cases of oral fibrous tumors in horses in spite of their relatively common occurrence. Older or mature horses appear to be more often affected. The buccal

gingivae of the maxillary cheek teeth are the commonest site, but they occasionally occur on the lingual margin and in the mandibular arcades.

Clinical features

A localized, fleshy, ulcerated and hemorrhagic mass is easily visualized lying usually alongside the maxillary cheek teeth (Fig. 11.4A,B). There may be some external distortion of the cheek outline with larger growths. Dysmimesis or hemoptalism may be noticed by an astute owner.

Diagnostic confirmation

Biopsy is essential to differentiate it from squamous cell carcinoma, sarcoid, and epulis, in particular.

Pathology

There are two forms of the oral fibroma. The first is a result of irritationally induced changes and is not a genuine neoplasm (see epulis above), and the second is a genuine (usually benign) neoplastic change in the fibroblasts. Pathologically, the latter are usually firm nodules that develop as aggregated protuberant tumors within a firm indurated plaque. They often ulcerate. Histologically they are very cellular with well differentiated fibroblasts arranged radially within a sparse extracellular matrix. Mitoses are usually evident but are not as common as in the more aggressive forms of fibrosarcoma. There may be deep extension into the subcutaneous fat. They are histologically distinctive and cannot really be confused with sarcoid.

Treatment

Treatment options are limited to surgical excision. Laser surgical excision or diathermy are effective and produce a relatively bloodless surgical field. It is important to clean/descale adjacent teeth of calculus at the same time in case the calculus acts as a focus for growth of a new mass.

Prognosis

These tumors are commonly considered to be very benign in behavior; most are slow-growing, and their treatment carries a good prognosis. There is no recorded suggestion that they are a precursor to squamous cell carcinoma, but in theory at least, fibrosarcoma could develop.

Ossifying fibroma

Definition

An ossifying fibroma is a poorly defined proliferative, fibro-osseous, tumor-like, solitary lesion, that typically develops in the rostral mandible, of younger horses in particular.

Occurrence

Most cases are reported in horses less than 1 year of age. They may, however, not be observed until the horse is handled at a later age, by which time there may be significant ulceration of the buccal mucosa and distortion of the underlying tissues.⁶⁸

Clinical features

The majority of these tumors occur unilaterally in the rostral mandible. They rarely develop in the maxilla and in very rare cases can be bilateral. They often reach considerable size and, initially, are covered by a domed, smooth/normal oral mucosa. Gross distortion of the lip and the associated teeth is likely. Later some ulceration is common (Figs 11.20A,B). There is some variation in the clinical presentation, with some lesions being flatter and fleshier in appearance; they can then resemble other soft tissue tumors. The expanding lesion also causes loosening of the teeth and consequent difficulty with prehension.

The tumor can predispose the mandible to pathological fracture. Although the lesions may frequently be clinically obvious, they may only be identified late in their course, probably because there is little indication to examine the mouth of many young horses.

Diagnostic confirmation

Radiographically the dense tissue is obvious with only some lesions showing the calcification more commonly encountered in other species (Fig. 11.20C). More ulcerated and secondarily infected lesions may resemble other soft-tissue tumors.

Pathology

Ossifying fibromas may develop as alterations in the growth characteristics of the periodontal membrane or the developing teeth. The masses are reported to arise from a sessile base on the surface of the bone and expand to replace and displace normal structures with dense fibrous or fibro-osseous tissue. The lesion has a dense, tough, well-circumscribed appearance; it may be extensively mineralized and difficult to cut. There is a characteristically abrupt histological transition from fibroblastic stroma to osteoblasts, which form spicules of osteoid. The dense gritty nature of the mass sometimes makes biopsy difficult.

Treatment

Surgical excision is curative provided that sufficient attention is paid to identifying the true extent of the abnormal tissue. Extensive surgical debulking followed by cobalt-60 teletherapy radiation and treatment using cobalt-60 teletherapy alone in a standing sedated horse have also been used successfully.⁶⁹ Hemimandibulectomy or hemimaxillectomy is also an effective option, particularly if the mandibular symphysis can be retained (Fig. 11.20D). Limited disabilities and acceptable cosmetic effects can be expected following treatment of more localized lesions. Cases subjected to this surgery should recover well and will usually cope well and lead active normal lives.⁶⁹ However, if extensive excision is required, it may leave unacceptable cosmetic and functional deficits.

Prognosis

Regrowth of the tumor is common because of the difficulty of identifying the margins of the abnormal tissue. All resected tissue should, therefore, be submitted for

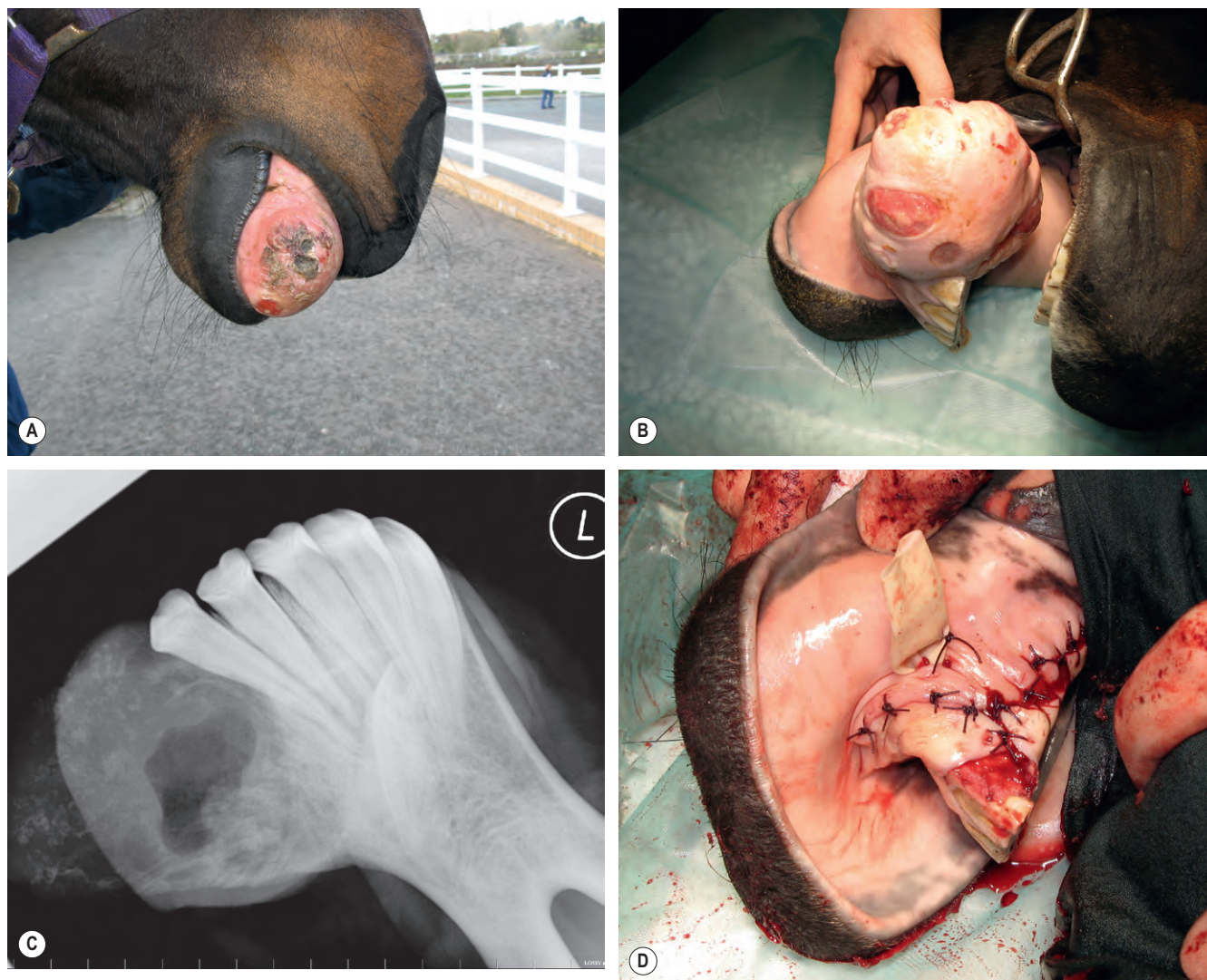


Fig. 11.20 (A, B) This ossifying fibroma was presented in a 3-year-old mare. (C) Radiographically the mass was found to involve the incisor teeth with loss of 203 and it had an obvious radiolucent center. A hemimandibulectomy (D) was performed with a good outcome.

histological examination, with particular attention paid to examination of the surgical margins, which need to be identified by the surgeon for the pathologist.

Myxomatous tumors of the jaw and gingivae

Definition

These are very rare tumors derived from embryonal connective tissue. The tumors are identified by their characteristic histological appearance.

Occurrence

In the few reported cases, older or mature horses appear to be more often affected. The incisor and molar dental arches of the maxilla are the most common sites.

Clinical features

These tumors are characteristically destructive (Fig. 11.21). The combined destruction and proliferation of tumor tissue

creates obvious distortion of the maxilla, with secondary nasal and sinus obstruction. Loosening of teeth and infection of alveolar bone may later result, but in the early stages there is usually little bone destruction (Figs. 11.22).

Diagnostic confirmation

Biopsy is essential. Radiographically, there is an aggressive lytic appearance of these lesions, with a diffuse mixture of bone and soft tissues, often in a partially loculated form. The cardinal radiographic signs of the more malignant forms, however, are the combined destruction of normal bone and bizarre irregular new bone formation in random arrangement. The radiographic appearance can be very similar to osteosarcoma (see above) and squamous cell carcinoma.

Pathology

This group of tumors includes a spectrum that extends from benign myxoma to malignant myxosarcoma. The tumors have a soft gelatinous gross appearance, and may be highly

infiltrative with a tendency to metastasize. Cut surfaces of the tumor may be lobulated and slimy. Histologically, the lesion contains characteristic stellate cells with abundant, amorphous extracellular matrix. These tumors can also resemble severely ulcerated juvenile ossifying fibroma, but the latter are usually slow growing and expansive rather than destructive. Additionally, ossifying fibroma has a characteristically different anatomic site, usually involving the rostral mandible.

Treatment

Treatment options are very limited – the margins of the tumor and their usual anatomical site make surgical excision virtually impossible. There are no definitive reports of

metastatic spread of the malignant forms of these tumors, but this may reflect the short clinical duration, which inevitably results in euthanasia before secondary tumors could develop elsewhere.

Prognosis

These tumors are very unpredictable in behavior; some are slow growing and remain relatively benign; others are highly aggressive and so carry a hopeless prognosis.

Oral hemangiosarcoma

This is a malignant neoplasm of endothelial cells that can arise in any part of the body. They are reported to metastasize early, and so tumors in any locality may be primary or secondary. There are few reports of this tumor in the mouth.^{70,71} Aged horses are more likely to develop them, and there may be concurrent tumors at other sites, such as around the eye (DCK, unpublished observation).

Clinical features

A red or purple ulcerated mass in the oral mucosa (on the sides of the tongue or the gingiva is typical). The mass is likely to be slow-growing and, being subject to repeated trauma, there may be oral hemorrhage. The lesions may be identified incidentally during a clinical examination, but where periocular lesions occur, the clinician should carefully examine all the visible mucous membranes, including the mouth, for other evidence of the tumor.

Differential diagnosis

Foreign-body reactions and ulceration arising from the attachments of *Gastrophilus* sp. may be similar.

Diagnosis

Biopsy is the only definitive way of establishing the diagnosis.

Pathology

Histological features are of a solid, soft-tissue sarcoma with marked anisocytosis, anisokaryosis, and myriad mitoses.

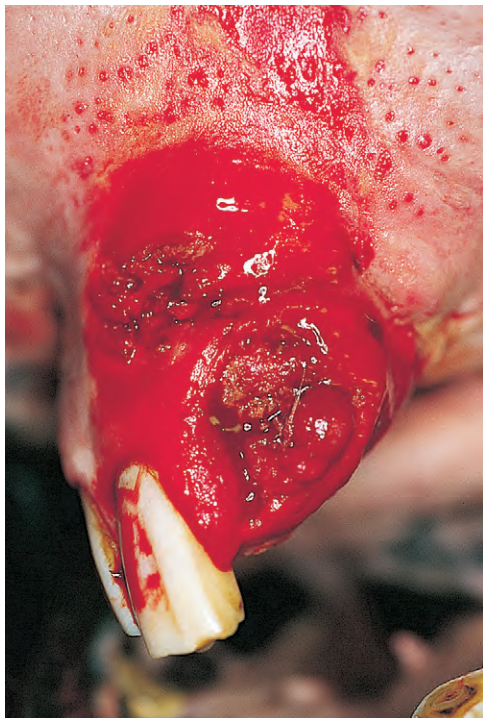


Fig. 11.21 Myxomatous tumor of the premaxilla in a 14-year-old hunter gelding. Note the extensive destruction that is very similar to squamous cell carcinoma. The diagnosis can be confirmed relatively easily by biopsy.

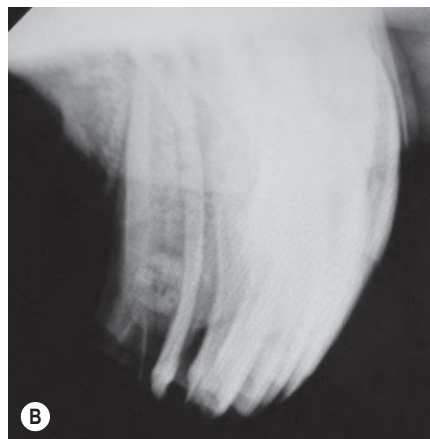


Fig. 11.22 (A) This malignant myxosarcoma was identified incidentally during routine dental treatment. (B) Radiographs showed only limited alveolar and maxillary bone involvement.

There is variable formation of large or small vascular channels lined with neoplastic endothelial cells. In histologically equivocal cases, immunohistochemical staining for Factor VIII-related antigen helps in identifying neoplastic endothelium. Tissue margins of resected lesions should be assessed carefully to ensure that excision is complete, although the latter may be difficult for tumors of the gingiva.

Treatment

Surgical excision may be effective but there are considerable technical difficulties and risks of incomplete excision. Where other tumors are also present elsewhere, local palliative treatment is all that can be advised.

Prognosis

The presence of more than one lesion may not necessarily indicate that the tumor has spread metastatically, but hemangiosarcoma is a malignant tumor of horses, and so this possibility must be considered.

Salivary adenocarcinoma

Salivary gland neoplasia is uncommon in horses. For example, in one study of 687 necropsies and 635 biopsies only three salivary tumors were described; two were carcinomas and one was a cystadenoma.⁴ Another review of 1148 equine tumors included only two salivary adenocarcinomas.⁷² Six of 14 documented equine salivary gland tumors were adenocarcinomas; where recorded, the sites of involvement were the parotid salivary gland (three cases) and the submandibular salivary gland (one case). The age range was 7–18 years.⁷³ Recognition is important because they are reported to be highly malignant, and up to 33 % may develop pulmonary metastases.

Clinical features

Recognition of salivary tumors is difficult, but, clinically, the affected gland becomes enlarged. Palpation is uncomfortable but not painful. Only one gland is involved, and so the enlargement is asymmetrical, which differentiates it from the more usual very benign and transient parotid salivary gland swelling commonly seen in grazing horses.

Differential diagnosis

Benign swelling of parotid salivary glands occurs frequently in grazing horses. This idiopathic condition is invariably transient and self-resolving. Obstruction of the salivary ducts by sialoliths (usually in the parotid gland) occurs within the gland substance or in the more rostral part of the duct. This results in a solid obstructive lesion with generalized glandular swelling. This remains hot and painful for some days before it subsides naturally as atrophy of the gland follows.

Diagnosis

Diagnosis is reliant upon biopsy, but so few cases have been described that a characteristic histological appearance is not established. Post-mortem histological features are described.¹⁵

Treatment

Surgical excision is theoretically possible if diagnosis is made sufficiently early, but this is unlikely in most cases.

Prognosis

The high malignancy of most salivary gland carcinomas makes the prognosis very poor.

Disorders of the jaws and teeth resembling neoplasms

Mandibular aneurysmal bone cyst

Although localized (usually very small) bone cysts are relatively common in long bones and in particular in their epiphyseal regions, mandibular cysts are very rare in horses. In man, they probably arise from circulatory disturbances within the bone structure⁷⁴ or traumatic alteration of the blood supply to a small area of bone.⁷⁵ While such structures might be expected in young horses, they may also occur in older horses, possibly as a result of trauma.¹⁰ There is no evidence to suggest that these lesions are truly neoplastic, but diagnosis based on radiographic examination alone is probably unwise. While there are no reports of concurrent neoplasia in the horse, complexes of tumors and cysts are reported in other species.

Clinical features

These bone cysts present as sterile, firm, expanding swellings usually on the horizontal ramus of the mandible (Fig. 11.23 A,B). The mandible becomes thickened from progressive destruction of cortical bone accompanied by reactive periosteal new bone formation. Some pain associated with mastication may develop, and teeth may be shed as their alveoli are destroyed. The region may be warmer than the normal contralateral mandibular ramus. The rate of expansion may be sufficient to cause disruption and bleeding into the surrounding tissues and may easily suggest the presence of a neoplastic lesion. As the destruction becomes more aggressive, the mandible may suffer a pathological fracture.

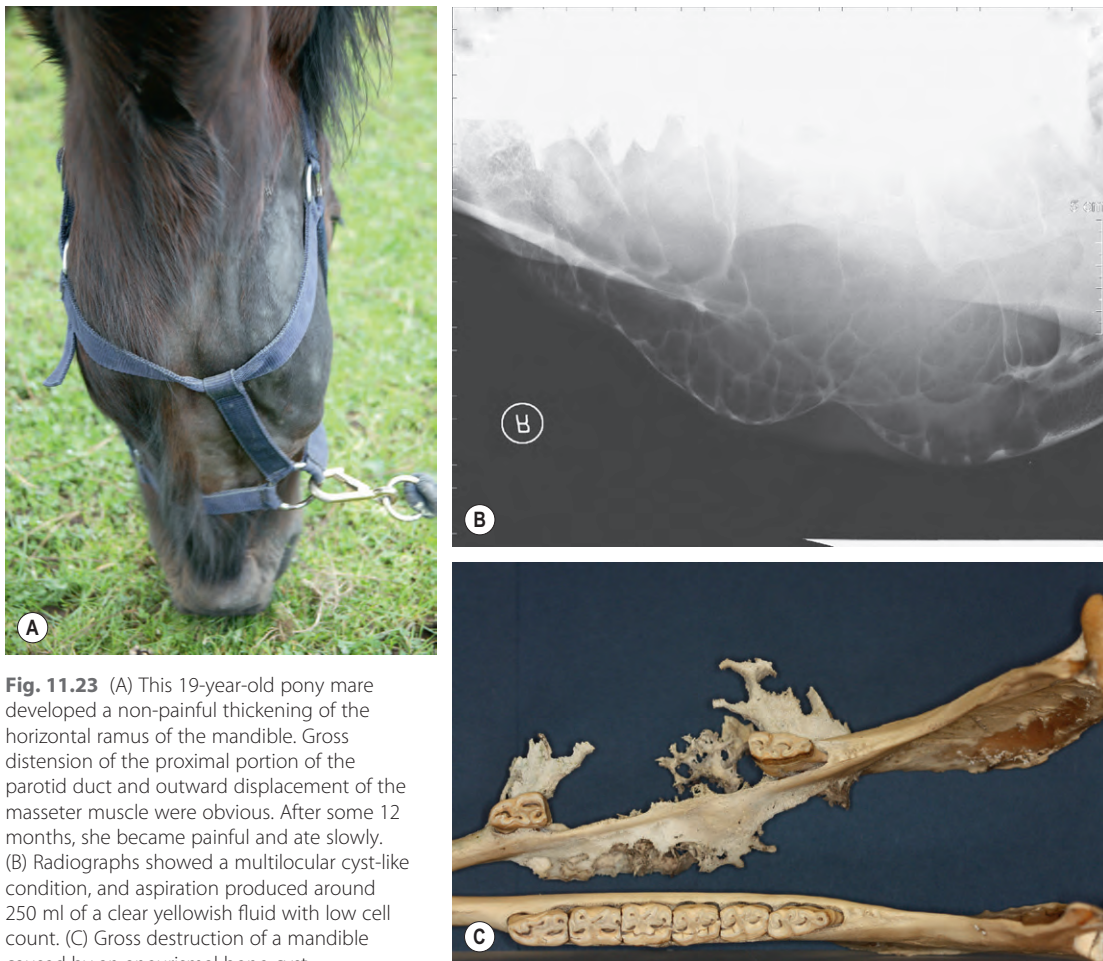
In advanced cases, the extent of bone destruction can be considerable (Fig. 11.23C), and pathologic fractures are now likely. Although parotid duct obstruction can occur, this is an insignificant clinical event.

Differential diagnosis

Ossifying fibroma and destructive ameloblastoma are the main differentials. Paranasal sinus cysts have a similar radiographic appearance but occur in a very different location.

Diagnosis

The radiographic appearance reveals a complex, loculated, cyst-like structure containing bone fragments and soft tissue, usually with a fine rim of thin bone around the periphery (Fig. 11.23B). The structure closely resembles a complex paranasal sinus cyst, which may also arise congenitally or develop at later ages. Aspiration of the affected mandible reveals small volumes of yellow or red-orange fluid.



Pathology

Histologically the cystic lesion contains bone fragments, granular debris, siderophages, multinucleated giant cells, and fibrovascular tissue with areas of organizing and free blood. Histological examination of curetted fragments of cyst contents may often correlate poorly with the radiographic appearance.

Treatment

The only effective treatment is deep and aggressive curettage of all abnormal tissue. The defect may be filled with cancellous bone grafts collected from a remote site. Repair may be slow, and the site may be cosmetically compromised, but some cases can be cured effectively. However, in most cases, treatment is not justified, and palliative care should be provided until euthanasia can be justified.

Prognosis

The prognosis is poor unless the lesions are detected early and treated with aggressive surgical ablation and suitable reconstructive measures. However, the chances of early diagnosis are low, and so the prognosis for these lesions is usually bleak. Complications including tooth loss and pathological bone fractures reduce the prognosis considerably.

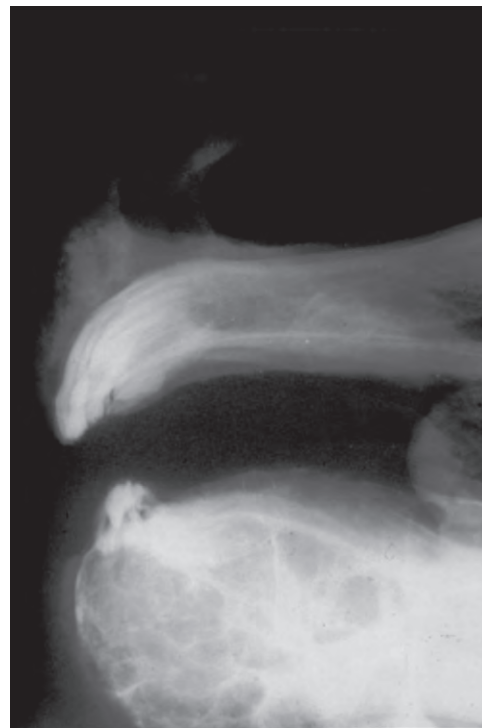


Fig. 11.24 A radiograph of fibrous dysplasia of the rostral portion of the mandible of a young horse.



Fig. 11.25 (A) Multiple discrete dermal nodules in a pony with histiocytic lymphosarcoma. (B) Cutaneous histiocytic lymphosarcoma with involvement of the gingival tissues. The ill-defined swellings of the gingiva were due to aggregations of abnormal lymphocytes. These lesions might easily be overlooked but are a regular finding in these cases. (C) Pharyngeal lymphosarcoma lesions that can sometimes be identified endoscopically. These lesions were symptom-free but larger ones can cause dysphagia. (D) Photomicrograph of the tongue from an aged horse with oral lymphosarcoma showing epithelium and diffuse subepithelial accumulation of neoplastic lymphoid cells. (E) Lymphosarcoma of the tongue showing neoplastic cells around and between muscle fibers.

Non-aneurysmal cystic lesions of bone

Non-aneurysmal cystic lesions of the jaws also present as bony swellings that may affect mastication. Radiographically the cysts differ from the multiloculated destructive aneurysmal cysts in being rounded with a smooth bony lining and radiolucent center. The generic term, odontogenic cyst, is appropriate for these non-inflammatory cysts lined by epithelium.²³ Radicular cysts occur adjacent to tooth roots. They are reactive lesions associated with oral inflammatory disease. Histologically they are lined by stratified squamous epithelium with associated inflammatory cells.

Fibrous dysplasia

Fibrous dysplasia of the bones of the skull has been reported in man,⁷⁶ and a clinically similar condition is recognized in

horses as a smooth contoured bone deformity arising from loss of bone structure with extensive formation of fibro-osseous matrix (Fig. 11.24). The lesion is probably not a true neoplasm, and its major effects in the jaw/face region are due to the expansive space-occupying nature of the slowly expanding mass. The changes are easily recognized histologically but may be confused with neoplastic lesions both radiographically and clinically. Suspicious masses should be subjected to the full range of diagnostic tests, including radiography, gamma scintigraphy, biopsy and, where feasible, computed tomography.

Pathology

Grossly normal bone is replaced by dense gritty tissue and may be surrounded by reactive bone. Histological features include fibrous dysplasia and the presence of 'naked'

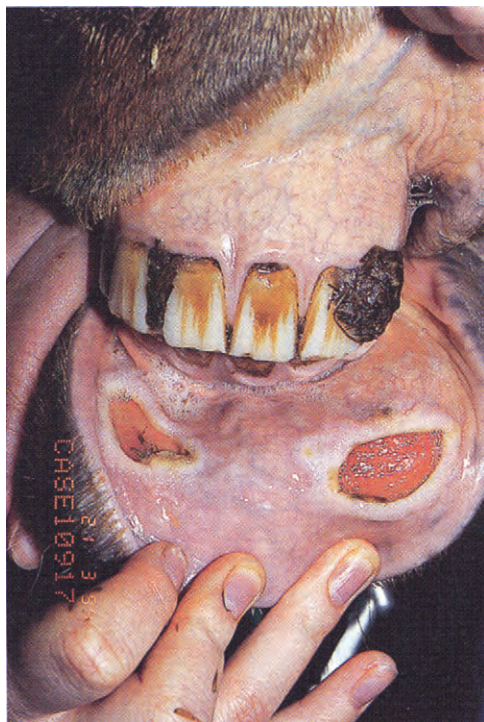


Fig. 11.26 Pituitary adenoma/Cushing's disease. Oral ulceration showing a singular lack of healing is a common sign (food is present on some teeth). Other dental and oral lesions may be present also.

spicules of woven bone in a dense fibrous stroma. The bone appositional surfaces lack recognizable osteoblasts.

Treatment

Surgical removal may be undertaken but many such lesions remain static and do not affect the horse.

Other tumors that may affect the mouth and jaws

Oral tumors arising by metastatic spread from remote organs and by invasion of the oral cavity from neighboring areas, such as the nasal cavity and paranasal sinuses can occur in horses. Tumors remote from the mouth and oral structures may have a serious influence on the mouth through metastatic spread (such as in hemangiosarcoma and lymphosarcoma). Secondary involvement of the mouth is, however, a

very rare event, even in highly malignant tumors and in any case, the oral signs may be trivial compared to the other systemic involvements. The mouth may be secondarily diseased through systemic effects from functional tumors such as the pituitary adenoma-related Cushing's disease and renal tumors.

Lymphosarcoma

Multicentric (generalized) and cutaneous histiocytic lymphosarcoma may have oral manifestations (Fig. 11.25). Usually the clinical appearance is of ill-defined nodular lesions of variable size embedded within and below the mucosal surface, which probably reflects the involvement of the normally-diffuse lymphoid tissue of the nasopharynx. The gingival mucosa is often affected. A similar nodular appearance is often present in the pharynx and in the sublingual tonsillar tissue where larger swellings may cause difficulty on swallowing. The lesions may ulcerate or become infected. Simultaneous submandibular lymphadenopathy, and other secondary effects, such as anemia, lethargy, and weight loss may signify serious systemic involvement.

Pituitary pars intermedia dysfunction (PPIDD / equine Cushing's disease)

Hyperplasia of the pituitary pars intermedia is responsible for secondary oral disease, such as extensive non-healing oral ulcers (Fig. 11.26), and dental and periodontal infections. The condition is regarded by some as a neoplasm of the pars intermedia, and is very common in older horses (usually > 14–17 years). Extensive dental and alveolar disease (including periodontal disease and periapical sepsis) commonly develops. This, with advancing age-related shortening of the residual crown of older horses, predisposes the affected animals to secondary sinusitis, and there may be tertiary consequences from this, including early shedding of teeth, oronasal and oromaxillary fistulae, oral ulceration and anemia.

Other distant tumors

Paraneoplastic changes, such as hypercalcemia and oral ulceration, can develop as a result of neoplastic disease in other tissues (usually myeloproliferative neoplasia).⁷⁷ It is important to remember that the mouth may be one of the early sites where clinical evidence of neoplastic disease, such as anemia, icterus, and azotemia, may be manifested. The lesions seen in the mouth may not be readily attributable to neoplastic disease either at a local or remote site.

References

1. Jackson C. The incidence and pathology of tumors of domestic animals in South Africa: a study of the Onderstepoort collection of neoplasms with special reference to their histopathology. *Onderstepoort Journal of Veterinary Science and Animal Industries* 1936; 6: 1–460
2. Hagdoost IS, Zakarian B. Neoplasms of Equidae in Iran. *Equine Vet J* 1985; 17: 237–239
3. Pirie RS, Tremaine WH. Neoplasia of the mouth and surrounding structures. In: Robinson NE, ed. *Current therapy in equine medicine*. WB Saunders, Philadelphia, 1997, pp 153–155
4. Sundberg JP, Burnstein T, Page EH, et al. Neoplasms of equidae. *J Am Vet Med Assoc* 1997; 170: 150–152
5. Smith P. *Large animal internal medicine*. Mosby, Philadelphia, 1996, p. 696
6. Baker GJ. Oral examination and diagnosis: Management of Oral Diseases. In: Harvey CE, ed. *Veterinary dentistry*,

- WB Saunders, Philadelphia, 1999, pp 217–220
7. Richardson DW, Evans LH, Tulleners EP. Rostral mandibulectomy in five horses. *J Am Vet Med Assoc* 1991; 199: 1179–1182
8. Purdy CM. Mandibular aneurysmal bone cyst in a horse. *Equine Practice* 1985; 7: 22–24
9. Verstraete FJM, Ligthelm AJ. Excessive granulation tissue of periodontal origin in a horse. *Equine Vet J* 1988; 20: 380–382
10. Lamb CR and Schelling SH. Congenital aneurysmal bone cyst in the mandible of a foal. *Equine Vet J* 1989; 21: 130–132
11. Gibbs C. The equine skull; its radiographic investigation. *Journal of the American Veterinary Radiology Society* 1974; 15: 70–78
12. Wyn-Jones G. Interpreting radiographs 6: Radiology of the equine head part 2. *Equine Vet J* 1985; 17: 417–425
13. McIlwraith CW. Equine digestive system. In: Jennings PB, ed. *The practice of large animal surgery*, WB Saunders, Philadelphia, 1984, p. 579
14. Moulton JE. Tumors in domestic animals, 3rd edn. University of California Press, Berkeley, 1990, pp 167–168
15. Head KW. Tumors of the alimentary tract. In: Moulton JE, ed. *Tumors in domestic animals*, 3rd edn. University of California Press, Berkeley, 1990, pp 347–374
16. Baker JR, Leyland A. Histological survey of tumors of the horse, with particular reference to those of the skin. *Vet Rec* 1975; 96: 419–422
17. Cotchin E. A general survey of tumors of the horse. *Equine Vet J* 1977; 9: 16–21
18. Gorlin RJ, Meskin LH, Brodey R. Odontogenic tumors in man and animals; Pathological classification and clinical behavior – a review. *Annals of the New York Academy of Science* 1963; 108: 722–771
19. Turrel JM. Oncology. In: Kobluk CN, Ames TR, Geor RJ, eds. *The horse: diseases and clinical management*. WB Saunders, Philadelphia, 1995, pp 1128–1130
20. Theon AP. Intralesional and topical chemotherapy and immunotherapy. *Veterinary Clinics of North America Equine Practice* 1998; 14: 659–671
21. Rols MP, Tamzali Y, Teissie J. Electrochemotherapy of horses: a preliminary report. *Bioelectrochemistry* 2002; 55: 101–105
22. Theon AP. Radiation therapy in the horse. In: *Veterinary clinics of North America equine practice* 1998, pp 673–688
23. Dubielzig RR. Tumors of the alimentary tract. In: Meuten DJ, ed. *Tumors in domestic animals*, 4th edn. Iowa State Press, Ames, Iowa, 2002, pp 402–410
24. Wahl P. Adamantinoma polycysticum ossificans am Unterkiefer eines Pferdes. *Deutsche Tierärztliche Wochenschrift* 1936; 46: 113–117
25. Peter CP, Myers VS, Ramsey FK. Ameloblastic odontoma in a pony. *American Journal of Veterinary Research* 1968; 29: 1495
26. Vaughan JT, Bartels JE. Equine mandibular adamantinoma. *J Am Vet Med Assoc* 1968; 153: 454–457
27. Hanselka DW, Roberts RE, Thompson RB. Adamantinoma of the equine mandible. *Veterinary Medicine for the Small Animal Clinician* 1974; 69: 157–160
28. Jones SL, Brumbaugh GW. Ameloblastoma in mandible of horse. What is your diagnosis? *J Am Vet Med Assoc* 1991; 199: 630–631
29. Summers PM, Wells KE, Adkins KE. Ossifying ameloblastoma in a horse. *Australian Veterinary Journal* 1979; 55: 498–500
30. Lingard DR, Crawford TB. Congenital ameloblastoma in a foal. *American Journal of Veterinary Research* 1970; 31: 801
31. Roberts MC, Groenendyk S, Kelly WR. Ameloblastic odontoma in a foal. *Equine Vet J* 1978; 10: 91–93
32. French DA, Fretz PB, Davis GD. Mandibular adamantinoma in a horse; radical surgical treatment. *Veterinary Surgery* 1984; 13: 165–171
33. Dillehay DL, Schoeb TR. Complex odontoma in a horse. *Vet Pathol* 1986; 23: 341–342
34. Dubielzig RR, Beck KA, Levine S, Wilson JW. Complex odontoma in a stallion. *Vet Pathol* 1986; 23: 633–635
35. Mason BJE. Temporal teratomata in the horse. *Vet Rec* 1974; 95: 226–228
36. Fessler JE. Heterotopic polyodontia in horses: nine cases 1969–1986. *J Am Vet Med Assoc* 1988; 192: 535–538
37. Lindshaw WA, Bech KA. Temporal teratoma in a horse. *Compendium of Continuing Education for Practicing Veterinarians* 1986; 8: 168–171
38. Kramer IRH, Pindborg JJ, Shear M. Histologic typing of odontogenic tumors 2nd edn. Springer-Verlag, Berlin, 1993, pp 151–156
39. Pindborg JJ, Kramer IRH, Torlini H. Histologic typing of odontogenic tumors, jaw cysts and allied lesions. *World Health Organisation*, Geneva, Switzerland, 1971, pp 145–154
40. Livesey MA, Wilkie IW. Focal and multifocal osteosarcoma in two foals. *Equine Vet J* 1986; 18: 407–410
41. Slayter MV, Boosinger TR, Pool RR, et al. Histological classification of bone and joint tumours of domestic animals, 2nd series, Volume 1. *Armed Forces Institute of Pathology*, Washington DC, 1994, pp 9–45
42. Thorp E, Graham R. A large osteosarcoma of the mandible. *J Am Vet Med Assoc* 1934; 84: 118–119
43. Jacobson SA. Parosteal osteoma juxtacortical osteogenic sarcoma in animals. *American Journal of Pathology* 1969; 58: 85a
44. Livesey MA, Wilkie IW. Focal and multifocal osteosarcoma in two foals. *Equine Vet J* 1986; 18: 410–412
45. Gorlin RJ, Meskin LH, Brodey RS. Odontogenic tumors in man and animals; pathological classification and clinical behavior – a review. *Annals of the New York Academy of Science* 1963; 108: 722–771
46. Straffuss AC. Squamous cell carcinoma in horses. *J Am Vet Med Assoc* 1976; 168: 61–62
47. Howie F, Munroe G, Thompson H, Murphy D. Palatine squamous cell carcinoma involving the maxillary sinus in two horses. *Equine Veterinary Education* 1992; 4: 3–7
48. Schuh JCL. Squamous cell carcinoma of the oral, pharyngeal and nasal mucosa in the horse. *Vet Pathol* 1986; 23: 205–210
49. Johnson PJ. Dermatologic tumors excluding sarcoids. *Veterinary Clinics of North America Equine Practice* 1998; 14: 625–658
50. Barker IK, van Dreumel AA, Palmer N. In: KVF Jubb, PC Kennedy, N Palmer, eds. *Pathology of domestic animals*, 4th edn, Volume 2, Academic Press, New York, 1993, p. 27
51. Knottenbelt DC, Pascoe RR. Diseases and disorders of the horse. Wolfe, London, 1994, p. 303
52. Henson WR. Carcinoma of the tongue in a horse. *J Am Vet Med Assoc* 1936; 94: 124
53. Leyland A, Baker JR. Lesions of the nasal cavity and paranasal sinuses of the horse causing dyspnoea. *British Veterinary Journal* 1975; 131: 339–346
54. Orsini JA, Nunamaker DM, Jones CJ, Acland HM. Excision of oral squamous cell carcinoma in a horse. *Veterinary Surgery* 1991; 20: 264–266
55. Theon AP. Cisplatin treatment for cutaneous tumors. In: NE Robinson, ed. *Current therapy in equine medicine*, 4th edn. WB Saunders, Philadelphia, 1997, pp 372–377
56. Paterson S. Treatment of superficial ulcerative squamous cell carcinoma in three horses with topical 5-fluorouracil. *Vet Rec* 1997; 141: 626–628
57. Pulley LT, Stannard AA. Tumors of the skin and soft tissues. In: Moulton JE, ed. *Tumors in domestic animals*, 3rd edn. University of California Press, Berkeley, 1990, pp 23–87
58. Knottenbelt DC, Edwards SER, Daniel EA. The diagnosis and treatment of the equine sarcoid. *Practice* 1995; 17: 123–129

59. Knottenbelt DC. A suggested clinical classification for the equine sarcoid. *Diagnostic Techniques in Equine Medicine* 2005; 3: 278–295
60. Pascoe RR, Knottenbelt DC. Neoplastic conditions. In: *Manual of equine dermatology*. WB Saunders, Philadelphia, 1999, pp 244–252
61. Brostrom H. Equine sarcoids: a clinical, epidemiological and immunological study. PhD Thesis, University of Uppsala, Sweden, 1995, pp 9–70
62. Theon AP. Cisplatin treatment for cutaneous tumors. In: Robinson NE, ed. *Current therapy in equine medicine*, 4th edn. WB Saunders, Philadelphia, 1997, pp 372–377
63. Knottenbelt DC, Kelly DF. The diagnosis and treatment of periorbital sarcoid in the horse: 445 cases from 1974 to 1999. *Veterinary Ophthalmology* 2000; 32: 169–191
64. Kelly DF. Diagnostic problems in nasopharyngeal amelanotic melanomas. *Equine Veterinary Education* 2003; 15: 25–26
65. Goetz TE, Ogilvie GK, Keegan KG, Johnson PJ. Cimetidine for the treatment of melanoma in 3 horses. *J Am Vet Med Assoc* 1990; 196: 449–452
66. Goetz TE, Long MT. Treatment of melanoma in horses. *Compendium of Continuing Education for the Practicing Veterinarian* 1993; 15: 608–610
67. Morse CC, Saik JE, Richardson DW. Equine juvenile mandibular ossifying fibroma. *Vet Pathol* 1988; 25: 415–421
68. Robbins SC, Arighi M, Ottewill G. The use of megavoltage radiation to treat juvenile mandibular ossifying fibroma in a horse. *Canadian Veterinary Journal* 1996; 37: 683–684
69. Kawcak CE, Stashak TS, Norrdin RW. Treatment of ossifying fibroma in a horse by hemimaxillectomy. *Equine Practice* 1996; 18: 22–25
70. Fry FL, Knight HD, Brown S. Hemangiosarcoma in a horse. *J Am Vet Med Assoc* 1983; 182: 287–289
71. Sweigard KD, Hattell AL. Oral hemangiosarcoma in a horse. *Equine Practice* 1993; 15: 10–13
72. Stackhouse LL, Moore JJ, Hylton WE. Salivary gland adenocarcinoma in a mare. *J Am Vet Med Assoc* 1978; 172: 271–273
73. Head KW. Salivary gland disease in domestic animals. In: de Burgh P, Norman JE, McGurk M, eds. *Salivary glands. Color atlas and text*. Mosby-Wolfe, Philadelphia, 1995, pp 367–389
74. Biesecker JL, Marcove RC, Huvois AG, Mike V. Aneurysmal bone cysts; a clinicopathological study of 66 cases. *Cancer* 1970; 26: 616–625
75. Dabezies EJ, D'Ambrosia RD, Chuinard RC, Ferguson AB. Aneurysmal bone cyst after fracture. *Journal of Bone and Joint Surgery* 1982; 64: 617–621
76. Jacobson SA. *The comparative pathology of the tumors of bone*. Charles C Thomas, Springfield, Illinois, 1971
77. Williams MA, Dowling PM, Angarano DW, et al. Paraneoplastic bullous stomatitis in a horse. *J Am Vet Med Assoc* 1995; 207: 331–334

Dental and oral examination

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Introduction

Oral and dental diseases are common occurrences in horses, as evidenced by the results of studies carried out on abattoir specimens.^{1–5} Signs of dental disease are often not apparent to the owner until the disease is well advanced.⁶ Casual dental examination as part of a complete physical examination is not sufficient to detect most equine oral or dental problems, as demonstrated by the reported high incidence and the comparatively low clinical diagnosis of dental disease.⁷ Clinical signs of dental disease are often not specific and may be reflected as systemic disorders, such as weight loss, diarrhea, colic, endocarditis, and septicemia, both in the horse and other species.^{8–14} In order to diagnose diseases afflicting the buccal cavity, the same degree of systematic rigor must be applied as would be the case during a lameness investigation.

A complete dental examination includes detailed observation and palpation of both hard (teeth and supporting bones) and soft oral tissues (lips, cheeks, tongue, palate, gingiva, oral mucosa, salivary glands, and ducts and muscles of mastication) for evidence of pathological changes.

The basis of modern clinical therapy is achieving an accurate diagnosis with information obtained by a clinical examination and ancillary tests. Although performing a comprehensive history and physical examination on every patient having routine dental work would be a valuable service to clients, this is not practical in most cases. However, one must identify any possible medical problems that may impact the safe delivery of dental care. The minimal dental examination must be thorough enough to detect abnormalities in their early stages of development. Treatment can then be initiated before irreversible damage occurs. The extent of the examination should be based on the information obtained in the history and the findings from the initial examination. Variations and/or abnormalities detected at the time of the examination must consistently be documented. A standard dental record form can be an invaluable aid in helping develop good examination habits (Fig. 12.1). Computerized dental records allow information to be more available for retrieval (Fig. 12.2).¹⁵

Equipment

The technique for restraint and size of equipment needed varies for different ages and sizes of equine patients. Very large (1000 kg or more) draft breeds need restraint with more heavily constructed equipment than the typical (500 kg) riding horse. On the other extreme, the pony (100 kg) and miniature breeds require smaller equipment. Oral examination and dentistry on small horses may also be aided by walking the horse up on an elevated platform to have the oral cavity at a more comfortable height for the operator's visualization and work plane. Equipment should include a large noseband halter, a metal-framed dental halter or head stand, mouth speculum, light source, oral irrigator, dental probes and picks, lingual and buccal retractors, and an intra-oral mirror or endoscope.^{16,17} Further details of this equipment are given in Chapter 16.

Dental signalment

Data on the horse's owner and trainer/manager/agent/groom should include their names, addresses, and means of contact. This is especially important for the person granting permission to work on the horse and the person responsible for payment of services rendered. The horse's insurance status and type of policy (mortality, loss of use, major medical, and surgical) should be recorded. Informed consent should be recorded before embarking upon any corrective procedures. Recording the stable name and address and the horse's location on the premises (barn number, paddock, stall number, etc.) can be helpful if re-examinations are needed. The horse should be identified on the record by name and described by breed, color, sex, age, type of work, and any special identifying markings, scars, brands, or tattoos.

Dental history

The dental history should focus on oral-, dental- and gastrointestinal-related areas. Special consideration must be given to other body systems related to masticatory function or issues that may affect the safety of the horse or

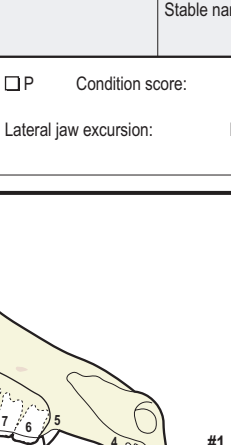
DENTAL EXAMINATION RECORD									
Date		Owner			Farm name/phone			Work phone	
Address				City		State	Zip	Home phone	
Horse reg. name				Stable name		Color		Breed	Sex
									Yr. foaled

Hair coat: ☐ Ex ☐ Vg ☐ G ☐ P Condition score: _____

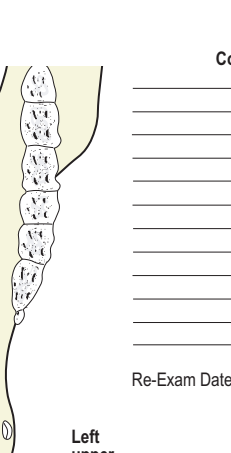
Feces: ☐ Fine ☐ Med. ☐ Coarse

D.age _____ Lateral jaw excursion: N AB Palpation: + -

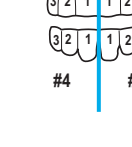
History: _____ Soft tissue _____

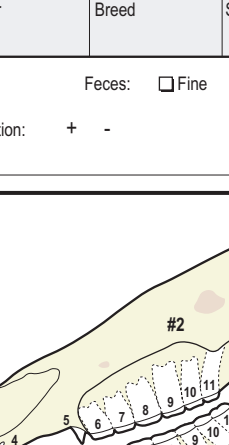


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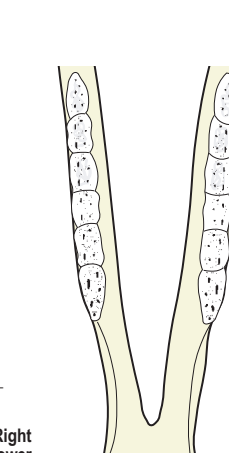


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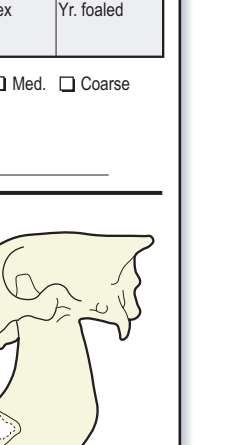




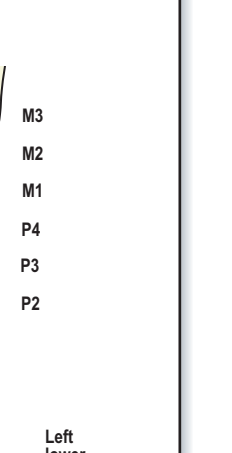
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Fig. 12.1 An equine dental record form.

veterinarian. A history of cardiac abnormalities, respiratory disease, renal problems, hepatic disease, or neurological signs could affect the way the animal is restrained for examination and treatment. The animal's breeding history and pregnancy status could have an effect on dental care scheduling, although it has been shown that it is safe to sedate mares at any time during gestation.^{18,19} Additionally, the horse's

show or race schedule may have an impact on when work is performed and whether drugs used to sedate or treat the horse could be considered prohibited substances. The owner should be questioned about the horse's fitness and type of exercise, temperament, stable vices, eating and drinking habits, fecal consistency, and physical abnormalities. Specific questions asked could begin with these examples: has

Salem Valley Veterinary Clinic
12 Center Street Salem, CT 06420 860-859-1649

Equine Dental Record

Client Name: John Doe

Date:

Horse's Name: Splash

Breed: Grade

Age: 20 +/- Sex: F

Oral examination

Soft tissue: Periodontal disease
at palatal diastema
Incisors: Normal

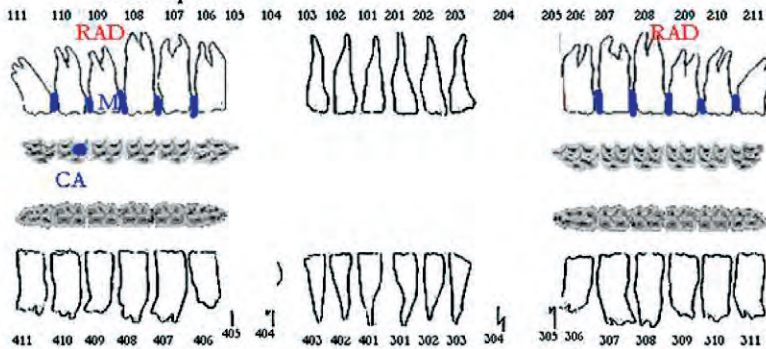
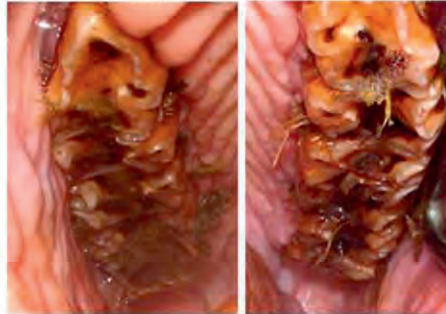
Wolf teeth: Absent

Canines: Absent

Molars: Multiple palatal
diastema, food packing
109 mobile

Infundibular decay 110

Enamel points



Procedures/Comments:

Float, periodontal Rx
(Air-abrasion)
Intraoral radiographs

Directions:

There is root abscessation of
the loose 109 molar; it should
be extracted.

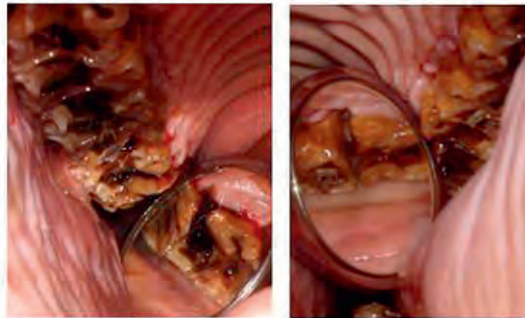


Fig. 12.2 Computerized equine dental record incorporating digital images.

the horse gained or lost weight over the past year? Have the horse's temperament or stable habits changed? Does the horse train well, and what type of bridle and bit does he wear? Have any changes been noticed in the horse's head carriage or demeanor when bitted? Does the horse make any noises or wear a tongue-tie when exercised? Details of the horse's eating habits and vices should be taken, and changes in eating or drinking patterns described.

Clinical detection of dental disease may at times be difficult because of the subtlety of signs. These may include reluctance to start eating, slow or intermittent eating, dribbling of food from the mouth (quidding), and head shaking or head tilting when eating. Sometimes, these signs are only detectable by careful direct observation of the mastication

process while the horse eats several different types of food. This can be time consuming, but it is often unwise to accept the owner's report of 'normal eating'.⁷⁸ Horses with sharp enamel points may pack forage in the buccal space, pushing the cheeks away from the upper teeth before eating grain. Information about water sources and drinking habits should be ascertained, and one should question if excessive salivation, oral malodor, or nasal or lacrimal discharge has been noticed.

The diagnosis of dental-related head shaking or bit resentment may be relatively easy in cases with obvious dental disease, but is often very difficult where there is no overt evidence. Head shaking is often attributed by lay persons to the presence of wolf teeth, their position, and/or



Fig. 12.3 Human hand infected with *Staphylococcus aureus*. Dental practitioners should wear gloves to protect against skin abrasions from sharp tooth points.

size. Likewise, horses with facial pain around the mental or infraorbital nerves may present with signs of head shaking.⁸

The horse's vaccination and deworming status should be determined. This is a good time to discuss these important preventative health topics, as further discussed in Chapter 4. Tetanus toxoid should be given to unvaccinated horses if corrective dental procedures, such as wolf tooth extraction, are performed or if oral abrasions occur during dental procedures. The owner should be questioned about the animal's history of infectious disease, as well as the presence of infectious or contagious disease on the farm. This information may affect the degree of sanitation used between patients on the premises and the degree of disinfection or sterilization of equipment and personal items required before visiting the next stables. Epidemiological studies have shown 10% of the horse population in some regions carry methicillin-resistant *Staphylococcus aureus* (MRSA). So, it is advised for operators working in the equine oral cavity to wear gloves (Fig. 12.3).²⁰

If the equine patient is being examined for a particular dental complaint, a complete history of the problem should be ascertained and documented. It has been shown that horses presented with a dental complaint are 5.8 times as likely to have one or more selected dental abnormalities.⁷ However, a complaint of a specific dental problem should not deter the veterinarian from obtaining a complete dental history and performing a thorough dental and physical examination.

Patient observation

Observation of the animal in its normal surroundings can provide information about stable management, eating habits, and vices. The area where the dental examination is

Table 12.1 Description of the numerical body condition score system²¹

- 1 Poor: emaciated. Prominent spinous processes, ribs, tailhead, and hooks and pins. Noticeable bone structure on withers, shoulders, and neck. No fatty tissues can be palpated.
- 2 Very thin: emaciated. Slight fat covering over base of spinous processes. Transverse processes of lumbar vertebrae feel rounded. Prominent spinous processes, ribs, tailhead, and hooks and pins. Withers, shoulders and neck structures faintly discernible.
- 3 Thin: fat built up about halfway on spinous processes, transverse processes cannot be felt. Slight fat cover over ribs. Spinous processes and ribs easily discernible. Tailhead prominent, but individual vertebrae cannot be visually identified. Hook bones appear rounded, but easily discernible. Pin bones not distinguishable. Withers, shoulders and neck accentuated.
- 4 Moderately thin: negative crease along back. Faint outline of ribs discernible. Tailhead prominence depends on conformation; fat can be felt around it. Hook bones not discernible. Withers, shoulders, and neck not obviously thin.
- 5 Moderate: back is level. Ribs cannot be visually distinguished but can be easily felt. Fat around tailhead beginning to feel spongy. Withers appear rounded over spinous processes. Shoulders and neck blend smoothly into body.
- 6 Moderate to fleshy: may have slight crease down back. Fat over ribs feels spongy. Fat around tailhead feels soft. Fat beginning to be deposited along the sides of the withers, behind the shoulders, and along the sides of the neck.
- 7 Fleshy: may have crease down back. Individual ribs can be felt, but noticeable filling between ribs with fat. Fat around tailhead is soft. Fat deposits along withers, behind shoulders, and along the neck.
- 8 Fat: crease down back. Difficult to palpate ribs. Fat around tailhead very soft. Area along withers filled with fat. Area behind shoulder filled in flush. Noticeable thickening of neck. Fat deposited along inner buttocks.
- 9 Extremely fat: obvious crease down back. Patchy fat appearing over ribs. Bulging fat around tailhead, along withers, behind shoulders and along neck. Fat along inner buttocks may rub together. Flank filled in flush.

performed must allow for safe restraint and should be free of obstacles that could injure the horse, an attendant, or the veterinarian. An area with a high ceiling shaded from bright sunlight with solid walls and a soft, non-slip floor is ideal. Access to warm water and electricity are beneficial.

The horse should be observed, and his temperament assessed. Hair coat and body condition should be evaluated by observation and palpation. Body condition scores range from 1–9, with 1 describing an extremely emaciated animal and 9 describing obesity (Table 12.1). The optimal condition score is between 5 and 6.²¹ Objective data, such as photographs and weight measured with a scale or tape can be recorded. These data can be a valuable tool in management of dental health and patient nutrition. The animal's posture and stance should be observed, and abnormalities such as swellings, injuries, and hoof problems should be brought to the attention of the owner/groom and noted in the record.

The stable floor should be surveyed for grain dropped from the horse's mouth or partially chewed boluses of quidded hay (Fig. 12.4). Feces should be examined for



Fig. 12.4 Horse dropping grain due to poor mastication secondary to periodontal disease.



Fig. 12.5 Manure from horse with poor mastication due to periodontal disease.

volume and consistency, as this can reflect how well the horse is masticating its feed (Fig. 12.5).²² Manure should be semi-moist, and fecal balls should be formed. Feces with long forage stems or whole grain indicate poor mastication. Long stems in poorly masticated feed can predispose the horse to esophageal choke, intestinal impaction colic, or diarrhea.

The horse's body and head type should be assessed and recorded. Head conformation can be reflected in the conformation of the dental arcades. Horses with short dished faces,



Fig. 12.6 Firm enlargement rostral and dorsal to facial crest. This horse suffered from an apical infection of 207 confirmed on radiographs.

typical of the Arabian breed, may have a more curved arcade with marked dorsal angulation of the lower 10s and 11s (exaggerated Curvature of Spee). Breeds that typically have long straight heads (Thoroughbred and some Warmblood breeds) are predisposed to malocclusion of the cheek teeth, leading to rostral and caudal cheek tooth overgrowth ('hook') formation. Miniature horses and ponies are more prone to dental overcrowding and subsequent misplaced or malerupted dentition.

Extraoral physical examination

During the basic physical examination (temperature, pulse, respiratory rate, auscultation of heart, lungs, and abdomen) the clinician can assess the horse's temperament. The examination should be performed using techniques of good horsemanship that gain the confidence of the horse and owner.

The head should be evaluated for symmetry, balance, and gross abnormalities that may give clues to dental problems. Standing at the horse's side, head shape and conformation should be assessed, and bumps or protuberances noted. Young horses between the ages of 2.5 and 4 years will have symmetrical, non-painful bony enlargements beneath the mandible and/or over the maxillary region as a result of normal eruption cyst development beneath the developing permanent teeth. If these enlargements are hot, swollen, asymmetrical, or associated with a draining tract, apical infection should be suspected (Fig. 12.6).

The eyes should be clear and free from lacrimal discharge. Standing directly in front of the horse, the ears, eyes, facial crests, and nasal bones should be symmetrical. The temporalis and masseter muscles and temporomandibular joints should be observed and palpated. The mouth should be opened slightly, and the frontal and maxillary sinuses percussed. The parotid salivary glands and intermandibular lymph nodes should be palpated, as should the ventral aspect of both sides of the mandible, for the presence of enlargements. The blood vessels and parotid salivary duct at

the rostral edge of the masseter muscle should be palpated. It has become popular to evaluate acupuncture points in the temporal region to aid in the diagnosis of dental or myofascial problems.²³ The hands should be placed under the nose band of a loose halter and pressure exerted on the cheeks at the level of the upper cheek teeth. Palpation from the level of the medial canthus of the eye, progressing rostrally over the masseter muscle to the level of the nasal notch, allows detection of abnormal wear patterns on the lateral aspect of the upper cheek teeth. If the horse resists this maneuver by tossing its head, it is most likely the result of pain from sharp enamel points pressing against the buccal mucosa. If such sharp points are present, they should be floated prior to using a full-mouth speculum. Otherwise, as the mouth is opened with the speculum in place, the cheeks are pushed tightly against the sharp enamel points, and the horse will object to opening its mouth and resist examination.

The nasal passages are observed and the false nostrils palpated, with any asymmetry of air flow, odor, or discharge from the nostrils noted. Sepsis of the cheek teeth commonly results in either nasal or paranasal sinus sepsis or respiratory obstruction.

The lips should be observed and palpated for bit injuries, noticing especially any scars or ulcers in the commissures, and any focal lesions that may indicate previous suppurative tracts from incisor apices. The lips of grey horses are a common site for melanomas. The upper lip should be rolled up and the underside examined for a tattoo (Table 12.2).

Table 12.2 A note on lip tattoos

Most horses that race in the USA are permanently identified with a freeze brand on the neck or a tattoo on the upper lip. Each breed registry has a different alphanumeric system for identifying horses by their upper lip tattoo.

The Jockey Club of North America uses an alphanumeric system that consists of a letter of the alphabet followed by numbers. The letter corresponds to the year the horse was foaled, with 1997 starting a new 26-letter series. Therefore, 1996 would be Z and 1998 would be B. Horses imported into the USA are identified with an asterisk (*) at the beginning instead of a letter.

The American Quarter Horse Association (AQHA) uses a more random alphanumeric system of five numbers in older horses and since 1983, four numbers followed by a letter. However, in 2009 the last books with the numbers followed by Z were sent out to lip tattooers. The new books will have a series of 5 numbers. In the past, AQHA has advised owners that a series of 5 numbers indicates a paint tattoo number. That will no longer be accurate in 2009 or later.

The American Paint Horse Association uses a numbering system that consists of five digits. The first digit corresponds to the last digit of the horse's year of birth. These first digits would be repeated every 10 years.

Since 1982, the United States Trotting Horse Association has used a system starting with A followed by three or four numbers (A in 1982 to Z in 2002). Horses born prior to 1982 were tattooed with three digits followed by a letter. Starting in 1996, 98% of trotters are freeze branded only.

Arabian and Appaloosa horses that race in the USA require lip tattoos for identification. Their six-digit registration number is tattooed on their upper lip.

The labial mucosa should be salmon-pink and glisten with saliva. Ulcers or erosions should be documented, and their cause determined, keeping in mind the possibility of viral lesions, such as vesicular stomatitis, which is a reportable zoonotic disease in some countries. If dental abnormalities are suspected from the history or examination, consider observing the horse eating before the mouth is washed for the oral examination and before sedation is administered.

When evaluating the horse's eating patterns, a distinction must be made between the horse having trouble with prehension and mastication and the horse that is dysphagic (unable to swallow). Prehension requires neuromuscular coordination and an intact jaw and incisor arcade. Mastication is usually altered by dental disease or abnormalities in the jaws, muscles, or temporomandibular joints. Tongue lesions or basal ganglion problems can also adversely affect prehension and mastication. Swallowing is a more complex process, and neurological, muscular, or mechanical abnormalities in the pharynx or esophagus should be considered in addition to dental disease. Rabies is a fatal zoonotic disease that, in its early stages in the horse, mimics other types of prehension and swallowing disorders. Equine practitioners and any assistants working in horses' mouths should be vaccinated for rabies and have antibody titers checked periodically in areas where rabies is endemic.²⁴

While standing in front of the horse, the lips are parted and the incisor teeth evaluated for number, shape, and symmetry. When viewed from the front, the occlusal line of the upper and lower incisors should be horizontal or parallel to the ground and the presence of diagonal incisor malocclusion is recorded (Fig. 12.7 A,B).²⁵ When viewed from the side, the incisor occlusal surfaces should be parallel to the angle of the facial crest, which is usually about 10–15° relative to the lower molar table surface. The incisors should be checked for anatomical characteristics used in assessing the horse's dental age, and the estimated age is then compared with the horse's real age, with a discrepancy between these two values possibly indicating abnormal incisor development or wear. It is important to acknowledge the variation between horses in their incisor appearance and real age^{26–29} (see Ch. 7). The incisors should be observed while the jaw is moved. Rostrocaudal movement of the mandible can be evaluated by observing the relationship between the upper and lower incisor when the chin is raised and lowered. A normal foal has 3–4 mm (adult horse 6–8 mm) of rostral-caudal jaw excursion when the head is raised and extended as much as possible and then flexed back into a vertical position.^{30,31} Horses with severe wear abnormalities, such as tall cheek teeth, focal overgrowths, or a step-mouth may have limited rostral-caudal range of mandibular motion.

Lateral jaw excursion is best evaluated by standing to one side of the horse and holding the head stationary with one hand on the bridge of the horse's nose. The other hand is used to grasp the mandible and, while pressing the mouth shut, move it from side to side. As the jaw is moved from one side to the other, the range of lateral movement present before contact is made by the cheek teeth (and thus separating the incisors) is recorded. The more rostral cheek teeth contact first, and the more caudal cheek teeth later contact as the jaw moves more laterally. Horses that have had their rostral cheek teeth reduced in height have to move the lower



Fig. 12.7 (A) 14-year-old American Quarterhorse with a facial curvature. This horse was injured as a yearling, and 208 did not erupt, leaving only 5 cheek teeth in the left upper arcade. (B) Incisors of the same horse, with diagonal incisor malocclusion (200/400 DIM).

jaw further before their incisors separate. Excursion to molar contact (EMC) is the distance the mandible travels laterally to cheek teeth contact. The average light breed horse has an EMC of 12.3 mm (SD = 3.1 mm), while miniature horses and ponies have an EMC of 5–6 mm, and draft breeds an EMC of 15–16 mm.^{32,33}

The second measurement noted in this procedure is the total lateral distance the mandible travels. By observing the incisors and listening to and feeling the molar arcades grind on one another, one can gain information about the occlusal slope of the cheek teeth and the symmetry of the occlusal contact between the upper and lower cheek teeth.^{34–36} The average light horse can move the center of the mandibular incisors laterally 45 mm ± 5 mm while chewing.³⁷ Normal lateral excursion produces a relatively even, subtle to moderate vibration and sound. Deviations from this can be an indication of abnormal dental contact due to cheek teeth overgrowths. It must be kept in mind that this maneuver does not replicate the chewing motion of the horse as outlined in Chapter 6. If the horse resists this part of the dental examination, sedation may be indicated to help the horse relax and allow a more thorough physical examination. With sedation, a complete dental examination can be carried out more safely and thoroughly, although the benefits of this may require explaining to some owners who may have an innate apprehension of the perceived side-effects of sedation (see Chapter 15).

Oral examination

The mouth is the window into the body. For too long, many equine veterinarians have assumed erroneously that the gastrointestinal tract starts with the esophagus. The oral mucous membrane is a thin sheet of tissue that permits the veterinarian to view changes in vessels and connective tissue beneath the oral mucosa. There are relatively few sensory nerve endings in the gingiva, which makes it a safe area to depress for observing vascularity and capillary refill time (CRT).

Male horses between 4 and 6 years old may have canine teeth in various stages of eruption. The upper canines usually erupt 2–8 months after the lowers. Eruption cysts or tenting of the mucosa with ulceration over these teeth can cause oral pain and biting problems. Long sharp canine teeth can be a danger to the examiner, and care should be exercised to avoid injury when manually examining the mouth. About 25 % of mares have one – four rudimentary canine teeth.³⁸ Dental calculus around the canines leading to gingivitis is common in older horses.

The upper and lower interdental spaces should be observed and palpated. By firmly running a thumb over the mucosa, one can feel for protuberances above or below the gingiva and observe the horse's response to pressure. The lower bars should be checked for bony irregularities, mucosal ulcers, or thickenings or the presence of wolf teeth.³⁹ Remodeling of the mandibular cortex rostral to the 2nd premolar can be palpated through the gingival mucosa and can indicate previous bit trauma, and may be associated with bit-sensitivity. The upper diastema is then palpated for bony abnormalities and the presence of wolf teeth. Unerupted wolf teeth, referred to as 'blind wolf teeth,' can cause oral discomfort and training problems in bitted horses. The distance from the commissures of the lips to the rostral edge of the first cheek teeth should be noted as this varies among horses. This distance affects the ease with which one works on the rostral teeth and may affect the most comfortable position of the bit in a working horse.

The tongue should be checked for function, and any anatomical abnormalities noted. Tongues are frequently injured from harsh bits or neglected tongue ties and from sharp teeth. The so-called 'lampas', or thickening of the palatal mucosa just behind the upper incisors, is common, and a normal feature in young horses that are erupting permanent dentition. The hand can be introduced into the interdental space and a thumb pressed on the hard palate to make the horse open its mouth. Great care should be exercised whenever a finger is placed in the mouth, to avoid serious injury.



Fig. 12.8 Horse sedated with head resting on a dental stand. The mouth is open with the speculum in place. The operator is seated in a comfortable position, allowing complete digital and visual examination of the oral cavity.

The easiest and safest way to thoroughly evaluate the oral cavity is by using a full-mouth speculum and a bright light source. Prior to placement of the speculum, it is advisable to rinse excess food from the mouth with a syringe, hose, or other device. To place the McPherson-type speculum in the mouth single-handed, the examiner stands to the left side of the horse. With the left hand holding the mouthpiece and the right hand holding the poll strap, the mouthpiece is introduced between the incisors in the same manner as a bit. The left thumb and forefinger are used to open the mouth and guide the mouthpiece into place between the incisors while the right hand applies steady tension to the halter strap from behind the horse's poll. When the speculum is properly positioned, the left hand tightens the halter's buckle to adjust the strap length until the speculum strap is snug. The bite plates are adjusted to square them with the incisors. A final check is made to ensure that the teeth and incisor plates are free of tongue, lips, and examiner's digits when opening the speculum. It is important to loosen the noseband and chin strap to allow a stable yet comfortable fit on the horse. The jaws of the speculum are opened one notch at a time alternating each side until the jaws are adequately opened. If the mouth cannot be opened with the speculum in place, the temporomandibular joints and bony structures of the jaw should be carefully evaluated before excessive force is placed on the jaw. At this point, the oral cavity is ready for visualization and palpation. Use of a head support stand or metal frame dental halter is recommended to elevate the head of a sedated horse to a comfortable height for good visualization and palpation (Fig. 12.8).

To examine the oral cavity, good illumination is critical. A battery-operated light that attaches to the upper incisor plate of the speculum or a powerful headlight provides good illumination while allowing both hands to be free for intra-oral procedures. A blade retractor fitted with an illuminator aids in the evaluation of the buccal recesses. A basket retractor keeps the tongue and buccal mucosa pulled away from the teeth for good visual access to the last few cheek teeth (Fig.

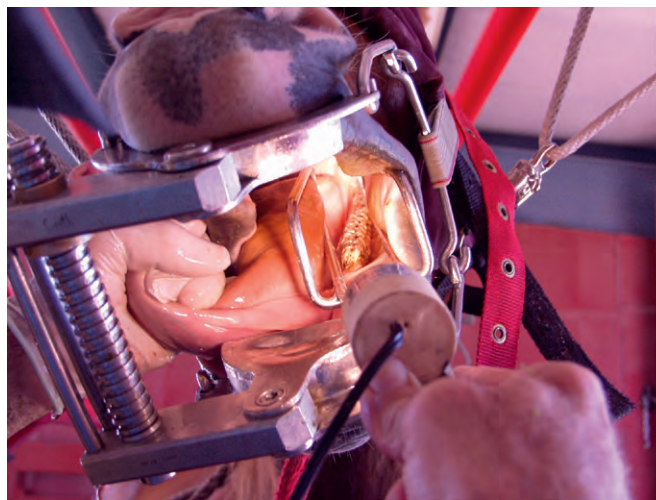


Fig. 12.9 View of the oral cavity with a mouth speculum, basket-type retractor, and attached light in place.



Fig. 12.10 Sharp enamel points on the 210 causing a deep buccal ulceration. This photo was taken using a rigid endoscope with a 45° optic.

12.9). The oral soft tissues should be observed with special attention paid to the palate, tongue, and buccal mucosa (Fig. 12.10). The teeth should be evaluated for conformation, position, number, and abnormalities. Enamel points on the buccal and lingual enamel folds or cingula usually do not protrude beyond the level of occlusal surface of the cheek teeth. The acute angle between the vertical edge of the tooth and the occlusal surface can cause sharp enamel points to look and feel quite prominent. A dental pick with a long shaft can be used to probe the four corners of the cheek teeth to detect and clean out periodontal pockets (Fig. 12.11A, B). A calibrated pick can be used to measure gingival pocket depth, which will range from 0.5–12 mm for normal teeth. It has been shown that gingival pocket depth measurements at the corners of the teeth significantly increases with periodontal disease.^{40,41} Defects have been found over the pulp horns on the occlusal surfaces of a large number of periapically infected teeth and can be detected by carefully probing

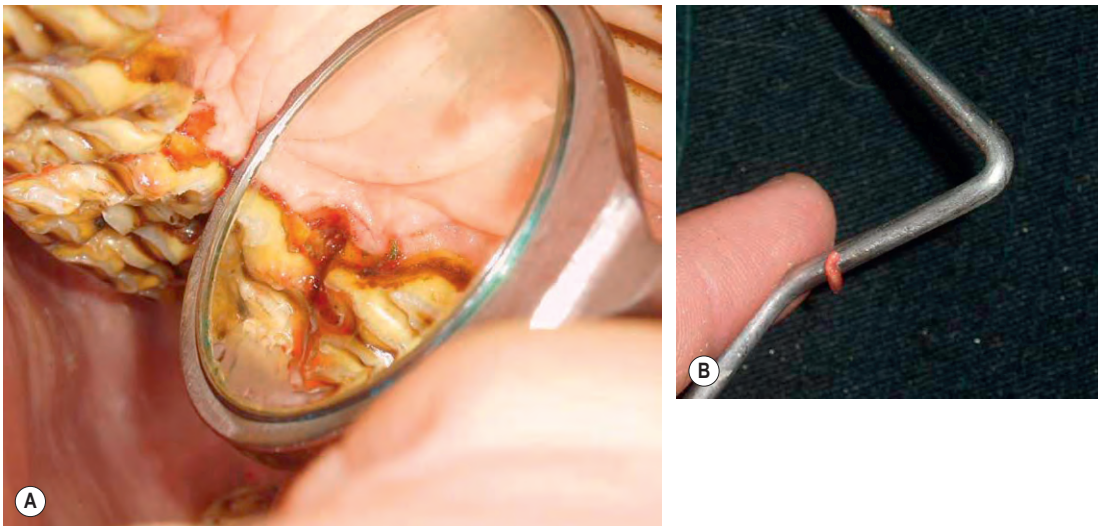


Fig. 12.11 (A) An equine oral mirror used to visualize an ulcerated area in the palatal tissue above a small diastema between 108 and 109. (B) A periodontal probe used to clean the pocket between 109 and 109. *Gastrophilus* (bot fly) larvae were removed from the shallow ulcerated area.



Fig. 12.12 A fine dental pick is used to explore the #1 pulp horn of 106. This pulp horn contained plant fibers in the area that should be covered with firm secondary dentin. This is a common finding in teeth with apical infections and pulpitis.



Fig. 12.13 The caudal aspect of the left lower dental arcade is ramped. The crown height above the gum helps determine whether this is a true caudal dental elongation (hook) or simply the last molar erupting in the curve of the jaw (Curvature of Spee).

the secondary dentin of the occlusal surfaces of suspect teeth (Fig. 12.12).^{3,42,43}

The oral cavity should be palpated, feeling the buccal, occlusal and lingual surfaces of all four arcades. The gingival margins of the cheek teeth should be uniform with no feed packed between them. The crown height should be the same on the rostral and caudal aspect of each tooth, but should be taller on the buccal aspect of the upper and the lingual aspect of the lower cheek teeth. Any deviation or asymmetry in the cheek teeth occlusal surface height or angle should be noted (Fig. 12.13). Each cheek tooth crown should be grasped between the thumb and forefinger and checked for stability, noting any movement or pain reaction. The occlusal surfaces of the cheek teeth should be palpated, noting any defects or asymmetry in the occlusal crown surface, bearing in mind that a defect in one cheek teeth row is usually reflected in a wear abnormality or defect in the opposite row.

An oral examination is not complete without evaluating the mouth with the aid of an equine dental mirror or ridged endoscope. A dental mirror designed for use in the horse's mouth needs to have a diameter of at least 5 cm set at 30–45° and should be set on a rigid shaft long enough to reach the back of the horse's mouth. Warming the mirror in hot water or applying an anti-fogging spray helps keep it clear. The rigid shaft allows the mirror to retract the tongue and buccal tissue as it is moved into the more caudal parts of the mouth. Oral endoscopy has been found to be superior to all other examination methods in identifying all types of dental disease, except for occlusal wear abnormalities (Fig. 12.14).^{44–47}

Oral endoscopy

Dental endoscopy facilitates the exploration, visualization, magnification, and recording of lesions of the oral cavity and



Fig. 12.14 Proper positioning for performing an oral endoscopic examination. The monitor should be positioned at the level of the horse's shoulder to allow good orientation.

has a great role to play in education as well as the demonstration and documentation of lesions within the oral cavity. Dental endoscopy enhances the diagnostic value of the oral examination and has become a routine part of dental and oral disease investigations.

Dental endoscopy can be performed with either a flexible fiberoptic or videoendoscope but is much easier using a rigid telescope, such as an instrument designed for human laparoscopy, which is less vulnerable to traumatic damage by the teeth.

A 40–50-cm telescope with a 30–90° viewing angle is ideal. The durability is improved if the telescope is protected in a stainless steel sheath. An additional outer plastic sheath is a useful addition to dampen any vibrations when the telescope contacts the rostral teeth during examinations. The telescope is coupled to a chip camera and monitor to enable viewing and, if necessary, recording of the images. More recently, a specifically designed oral endoscope, angled at 90° to the shaft with chip camera and image capture, has become commercially available.

Horses should be sedated for dental endoscopic examinations. The ideal depth of sedation results in the horse resting its chin on a stand or suspended halter with a low probability of upward jerking of the head. Tongue movement can impair a thorough endoscopic examination. Additional muscle relaxation can be achieved using 5–10 mg of diazepam, IV.

The endoscopic examination is always preceded by a thorough visual and digital examination of the oral cavity. Start with examining the occlusal surfaces and buccal and lingual aspects of all teeth beginning with cheek tooth 106 and then advancing the endoscope caudally, inspecting each occlusal



Fig. 12.15 Double crown fracture of 210. Buccal and lingual slab fracture fragments have been lost, and the surrounding gingiva healed. This photo was taken using a rigid endoscope with a 90° optic.



Fig. 12.16 Endoscopic occlusal view of an apically infected 409. A flexible probe has penetrated the degenerate secondary dentin overlying the #1 pulp horn. This photo was taken using a rigid endoscope with a 90° optic.

surface in turn, and noting any defects in the occlusal surface that may be of pathological significance (Fig. 12.15). Any potential defects in the surface, particularly of the secondary dentin corresponding to the pulp horns or areas of infundibular cemental hypoplasia, are re-examined while inserting a fine occlusal probe or pick into the defect (Fig. 12.16). The endoscope is then rotated and repositioned to examine the palatal mucosa and interdental spaces, noting any fibrous food entrapment and diastema.

The endoscope is finally rotated to the buccal aspect of 106, and advanced caudally to identify diastema, displaced teeth and in particular, mucosal ulcers. The gag may need to be loosened slightly to enable sufficient cheek tooth retraction to thoroughly explore the buccal mucosa. Deep periodontal pockets are thoroughly cleaned using a pick and water jet and then re-examined for the presence of inflamed or granulating tissue (Fig. 12.17). The findings for each arcade are annotated into the dental chart, and the second arcade commencing with 206 is examined. The mandibular arcades are examined in a similar fashion. When examining the mandibular arcades, the lingual aspect of the arcade may be visualized more successfully if the tongue is retracted.

Oral endoscopy has been invaluable in the identification of open pulp horns, infundibular caries, periodontal disease, and oral soft tissue lesions, which are almost impossible to



Fig. 12.17 Endoscopic view of a 310–311 diastema 3 months after periodontal treatment. Feed is no longer packing in the periodontal pocket, and the mucosa is healed. This photo was taken using a rigid endoscope with a 90° optic.

identify on the most thorough visual examination. The presence of small fissures in the secondary dentine may indicate a communicating tract between the oral and pulp cavities, or previous pulpal insult that has resulted in failure of secondary dentin production in the coronal pulp horn. A fine pick can be inserted into the fissure in an attempt to determine its depth. Infundibular cemental hypoplasia is commonly observed by dental endoscopy. The size and shape of the infundibula depends on the age of the horse. In young horses, the presence of wider infundibula that resemble incisor cups, is normal. In older horses, infundibular cemental hypoplasia most commonly affects the 109 and 209, and increases the likelihood of food impaction and decay (Fig. 12.17). After removal of the entrapped food, the extent of inflammation associated with periodontitis and the depth of periodontal pockets, can be assessed. The angled view and magnification provided by endoscopy often reveal small buccal or lingual ulcerations.

Ancillary diagnostic tests

If the initial dental examination findings reveal signs of dental disease, other diagnostic techniques can be employed to make a more definitive diagnosis. Where plant awns or bot fly larva are detected, soft tissue lesions inside the oral cavity should be assessed grossly, and surface scrapings taken for microscopic evaluation. Larger oral masses can be biopsied for histopathology. Molecular methods of tissue testing permit definitive identification when standard culture and phenotypical criteria are inconclusive (see Ch. 11). Skull radiographs, both plain and contrast film studies, and intra-oral radiographs give added information about dental, osseous, and sinus structures⁴⁸ (see Ch. 13). Other imaging modalities, such as ultrasonography, computerized tomography, nuclear scintigraphy, or fluoroscopy may reveal a more accurate picture of some dental abnormalities.

Disease of the upper last four cheek teeth may be associated with sinus disease, commonly presenting with unilateral nasal discharge. Endoscopy of the nasal passages can

confirm whether or not the discharge is coming from the nasomaxillary opening. Malerupted teeth have been seen to obstruct the nasal passages, which can make passing an endoscope difficult if not impossible on the affected side. Sinuscopy has been valuable in diagnosing and treating some sinus disorders without the need for exploratory flap sinusotomy, as described in Chapter 14.^{49,50,51}

Dental records and treatment planning

The horse's signalment, use, and management should be recorded. Pertinent history should be noted, with special emphasis on digestive system or performance problems. The horse's general body condition should be recorded, and a numbered body score assigned. The results of the masticatory system examination should be recorded, and problems listed in order of significance. A plan for treatment of each problem should be outlined based upon the results of history, clinical findings, and oral examination before proceeding with any dental work. This problem-orientated approach is important because the owner and/or trainer should be informed of any abnormalities, given a plan for treatment, and an estimate of the cost before any corrective procedure is performed. An owner consent statement is often included in record forms and can minimize problems should a legal claim be filed against the veterinarian or a bill come in dispute for collection. Recording images, videos, and radiographs digitally allows these images to be incorporated in the computerized dental record.^{15,32}

Oral and dental charting

Charting is the process of recording the state of health or disease of the teeth and the oral cavity.⁵³ To properly chart the mouth, the dental formula and anatomical locations in the mouth must be standardized to make documentation consistent. Use of standard abbreviations for dental terms to describe anatomical boundaries, abnormalities, diagnostics and therapeutic procedures make communication possible between equine practitioners and other colleagues in both the veterinary and human dental professions.^{16,54}

The American Veterinary Dental College Nomenclature and Classification Committee has endorsed the use of the Triadan tooth numbering system^{55,56} (see Ch. 5).

To fully understand equine tooth development and anatomy and to properly document abnormalities for dental record keeping, certain oral topographical terms have been defined. For a unique identification of each surface of a tooth, the following descriptions are used:

- Apical: toward the apex (or root once developed)
- Occlusal: masticatory surface
- Vestibular: toward the vestibule of the cheeks or lips
- B buccal: toward the cheeks
- Labial: toward the lips
- L lingual: toward the tongue in the upper or lower arcade
- P palatal: toward the palate in the upper arcade
- IPM or D: proximal or interproximal: between teeth, mesial or distal
- Mesial: anterior or rostral (interproximal surface nearest to mandibular symphysis)

- Distal: posterior or caudal (interproximal surface farthest from mandibular symphysis).

Computerized dental charting and record keeping are used in human and veterinary dentistry. Standardized abbreviations and record forms are essential to make this transition into equine practice. Some common dental abnormalities and a standardized grading system are presented to help chart dental findings in a uniform manner. The system presented here has been proposed by the American Academy of Veterinary Dentistry and the American College of Veterinary Dentistry but other systems and abbreviations are in use.

- TO: tooth overgrowth: for incisors determined after cheek teeth reduction to achieve arcade balance.
- MAL2: Class II malocclusion, overbite, brachygnathism, parrot mouth.
- MAL3: Class III malocclusion, underbite, prognathism, monkey mouth.
- CV: ventral curvature of the incisor arcade, 'smile'.
- CD: dorsal curvature of the incisor arcade, 'frown'.
- DGL or DIM: diagonal incisor arcade. Given a number with respect to which lower incisor arcade is the longest. (i.e., DGL/4, 400 arcade longer or the two longer arcades 200/400DIM). (See Fig. 12.7.)
- PTS: sharp enamel points (these can affect individual teeth, entire rows of teeth, or all four arcades uniformly). These enamel elongations have been classified as mild (1–3 mm tall), moderate (3–5 mm tall), severe (>5 mm).⁴⁷
- HK: crown hook, elongation longer than wide.
- BK: beak, small enamel point on the ends of the arcade.
- RMP: ramp, elongation wider than long.
- STP: step.
- WV: – wave.
- ETR: excessive transverse ridge.
- CUPD – cup in central portion of crown.
- TC: tall crown.
- BI (L, A, or U): buccal injury (laceration, abrasion, ulcer).
- LI (L, A, or U): lingual injury (laceration, abrasion, ulcer).
- PD: periodontal disease, stage 1–4.
- PP: periodontal pocket, a depth in mm can be assigned.
- FX: fracture.
- CAL: calculus.
- RD: retained deciduous cap.
- CA: caries.
- INF/CA-infundibular caries, grade 1–5.
- SN: supernumerary.
- O: missing tooth.
- WC: worn crown.
- ROT: rotated.
- X: extraction, simple.
- 506X, 606X, etc. (cap extraction or retained deciduous tooth removal).
- 105X (wolf tooth extraction).
- XSS: surgical extraction.
- OD: odontoplasty (reduction of excessive crown from occlusal surface).
- FTL: float (reduction of lingual and buccal enamel points).

- BS: bit seat (rounding the rostral margins of 2nd premolars).
- I/OD: incisor odontoplasty: incisor crown reduction.
- TI: 'tooth impacted', 'blind' (not completely erupted and completely or partially covered by bone or soft tissue).
- RRT: retained root tip.
- RTR: retained tooth root.

Other shorthand systems have been used to grade or stage dental lesions.

Periodontal Disease Index adapted for equine anatomy⁵⁷

- 0 Normal
- 1 Local gingivitis with hyperemia and edema: no attachment loss (probing depth, less than 5 mm)
- 2 Early periodontal disease (less than 25% attachment loss)
- 3 Moderate periodontal disease (less than 50% attachment loss or bone loss)
- 4 Advanced periodontal disease (more than 50% attachment loss or bone loss)

Tooth Mobility Index⁵⁷

- 0 Normal with no crown mobility
- 1 First distinguishable sign of movement up to 0.5 mm
- 2 Movement of the crown up to 3 mm
- 3 Movement greater than 3 mm in any direction.

Grading of infundibular caries³

- Grade 0 – No visible caries
- Grade 1 – Caries of the infundibular cementum
- Grade 2 – Caries of infundibular cementum and surrounding enamel
- Grade 3 – Caries of infundibular cementum, enamel, and dentin
- Grade 4 – Splitting of the tooth as a result of caries
- Grade 5 – Loss of tooth due to caries.

This system is used on the sample dental charts provided. A dental chart can be used to record the examination, assessment, and pathology. A second diagram can be used to denote the specific treatment and post-treatment result or a single diagram can be used as a combined report form.

Summary

The basis for a complete equine dental examination is the development of a routine treatment plan that is used on each patient. By utilizing proper restraint techniques and equipment, a thorough examination can be performed with minimal stress to the horse and risk of injury to the veterinarian. Finally, a complete written record of the dental examination, findings, treatment plan, and follow-up recommendations is essential for the long-term management of equine oral health. For a visual demonstration of the oral examinations, view the accompanying DVD.

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References

- Kirkland K, Marretta SM, Inoue OJ, Baker GJ. Survey of equine dental disease and associated oral pathology. *Proc Am Assoc Eq Pract* 1994; 40: 119–120
- Baker GJ. Some aspects of equine dental disease. *Equine Vet J* 1997; 2: 105
- Baker GJ. A study of equine dental disease. PhD Thesis, University of Glasgow, 1979, pp 78–82
- Wafa NS. A study of dental disease in the horse. MVM Thesis. National University of Ireland, University College, Dublin, 1988, pp 1–188
- du Toit N, Gallager J, Burden FA, Dixon PM. Post mortem survey of dental disorders in 349 donkeys from an aged population (2005–2006). Part 1: Prevalence of specific dental disorders. *Equine Vet J* 2008; 40: 204–209
- Greene S, Basile T. Recognition and treatment of equine periodontal disease. *Proceedings of the 48th Annual Convention of the American Association of Equine Practitioners* 2002: 463–466
- Uhlinger C. Survey of selected dental abnormalities in 233 horses. *Proceedings of the 33rd Annual Convention of the American Association of Equine Practitioners* 1987, pp 577–583
- Knottenbelt DC. The systemic effects of dental disease. In: Baker GJ, Easley J, eds. *Equine dentistry*, 1st edn. WB Saunders, London, 1999, pp 127–138
- Baker GJ. Dental physical examination. *Veterinary Clinics of North America, Equine Practice*, 1998; August, 247–257
- DeBowes J, Mosier D, Logan E, et al. Association of periodontal disease and histologic lesions in multiple organs in 45 dogs. *J Vet Dent* 1990; 13: 57–60
- Verdegaal E JMM, DeHeer N, Meertens NM, et al. A right-sided bacterial endocarditis of dental origin in a horse. *Equine Vet Educ* 2008; 24: 245–250
- Tamzil Y. Chronic weight loss syndrome in the horse: a 60 case retrospective study. *Equine Vet Educ* 2006; 372–378
- Pavlica Z, Petelin M, Juntjes P, et al. Periodontal disease burden and pathological changes in organs of dogs. *J Vet Dent* 2008; 25: 97–105
- duToit N, Burden FA, Dixon PM. Clinical dental examinations of 357 donkeys in the UK: part 2, Epidemiological studies on the potential relationships between different dental disorders, and between dental diseases and systemic disorders. *Equine Vet J* 2009; 41(4): 395–400
- Earley ET. Creating a dental form for interactive use in the field. *Proc Am Assoc Eq Pract* 2002; 48: 453–457
- Geiche JM. How to assess equine oral health. *Am Assoc Eq Pract Proceedings* 2007; 53: 498–503
- duToit N, Burden FA, Dixon PM. Clinical dental examination of 357 donkeys in the UK: part 1, Prevalence of dental disorders. *Equine Vet J* 2009; 41(4): 390–394
- Ohnesorge VB, Deegon E, Jochle W. *Berlin tierarztl wochensche* 1991;104: 340–346
- Luukkanen L, Katila T, Koskinen E. Some effects of multiple administration of detomidine during the last trimester of equine pregnancy. *Equine Vet J* 1997; 5: 400–402
- Anderson MEC, Weese JS. Review of methicillin-resistant *Staphylococcus aureus* in horses and veterinary personnel who work with horses. *Am Assoc of Eq Pract Proceedings* 2008; 54: 301–304
- Henneke DR. A condition score system for horses. *Eq Pract* 1985; 7: 13–15
- Carmalt JL, Allen A. The relationship between cheek tooth occlusal morphology, apparent digestibility and ingesta particle size. *Am Assoc Eq Pract Proceedings* 2008; 54: 386–389
- May KJ. Relationship between acupuncture, chiropractic, and dentistry. *Large Animal, Equine N Am Vet Conf*, Orlando 2008; 141–144
- Centers for Disease Control and Prevention: Humane rabies prevention-United States (1999) Recommendations of the Advisory Committee on Immunization Practices (ACIP). *Morbidity, Mortality Weekly*, 1999, 48 (No RR-1)
- DeLorey MS. A retrospective evaluation of 204 diagonal incisor malocclusion corrections in the horse. *J Vet Dent* 2007; 24: 145–149
- Walmsley JP. Dental aging in horses between five and seven years of age. *Equine Vet Educ* 1993; 5
- Richardson JD, Lane JF, Waldron KR. Is dentition an accurate indication of age in the horse? *Vet Record* 1994; 135(2): 31–34
- Richardson JD, Cripps PJ, Lane JG. An evaluation of the accuracy of ageing horses by their dentition. *Vet Record* 1995; 137(5): 117–121
- Muylls S, Simoens P, Lauwers H. Aging horses by an examination of their incisor teeth: an (im)possible task. *Vet Record* 1996; 138(13): 295
- Allen T. Examination. In: T Allen, ed. *Manual of equine dentistry*. Mosby, St Louis, 2003, pp 49–53
- Carmalt JL, Townsend HGG, Allen AL. Effect of dental floating on the rostrocaudal mobility of the mandibles of horses. *J Am Vet Med Assoc* 2003; 223: 666–669
- Rucker BA. Equine cheek teeth angle of occlusion: how to calculate and clinical use for incisor shortening. *Equine Vet Educ* 2004; 176–182
- Rucker BA. Excursion to molar contact. *Am Assoc Eq Pract Dental Wet Lab Notes*, Lexington, KY, 2008, pp 31–37
- Rucker BA. Incisor procedures for field use. *Am Assoc Eq Pract Proceedings* 1996; 41: 22
- Rucker BA. Utilizing cheek teeth angle of occlusion to determine length of incisor shortening. *Am Assoc Eq Pract Proceedings* 2002; 48: 448–452
- Rucker BA. Incisor and molar occlusion: how to determine the cheek teeth angle of occlusion in clinical cases. *Am Assoc Eq Pract Dental Wet Lab Notes* 2005, pp 1–10
- Collinson M. Food processing and digestibility in horses. BSc dissertation. Monash University, Victoria, 1994, pp 36–42
- Miles AEW, Grigson C. *Colyer's variations and diseases of the teeth of animal* (revised) Cambridge University Press, Cambridge, 1990, p. 121
- Johnson TJ. Surgical removal of mandibular periostitis (bone spurs) caused by bit damage. *Am Assoc Eq Pract Proceedings* 2002; 48: 458–462
- Stock S. Periodontal parameters in the normal and pathological equine tooth. *World Equine Dental Congress Proceedings* 1997, pp 92–95
- Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease part 2: a long term study of 400 cases: disorders of development and eruption and variations in position of cheek teeth. *Equine Vet J* 1999; 31: 519–528
- van den Enden MSD, Dixon PM. Prevalence of small occlusal pulpar exposure in 110 equine cheek teeth with apical infections and idiopathic fractures. *Vet J* 2008; 178: 364–371
- duToit N, Burden FA, Kempson, SA, et al. Pathological investigation of caries and occlusal pulp exposure in donkey cheek

- teeth using computerized axial tomography with histology and ultrastructural examinations. *Vet J* 2008; 178: 387–395
44. Tremaine H. Equine endoscopy in the horse. *Cl Tech in Eq Pract* 2005; 4: 181–187
 45. Goff C. A study to determine the advantages of oral endoscopy for the detection of dental pathology in the standing horse. *Am Assoc Eq Pract Proceedings* 2006; 52: 266–268
 46. Easley J. How to perform and interpret an endoscopic examination of the equine oral cavity. *Am Assoc Eq Pract Proceedings* 2008; 54: 383–385
 47. Simhofer H, Griss R, Zenter K. The use of oral endoscopy for detection of cheek teeth abnormalities in 300 horses. *Vet J* 2008; 178: 396–404
 48. Barakzai SZ, Dixon PM. A study of open-mouthed oblique radiographic projections for evaluating lesions of the erupted (clinical) crown. *Equine Vet Edu* 2003; 5(3): 183–188
 49. Freeman DE. Sinus disease. *Vet Clinics N Am Eq Practice* 2003; 19: 209–243
 50. Ruggles AJ, Ross MW, Freeman DE. Endoscopic examination of normal paranasal sinuses in horses. *Vet Surg* 1991; 20: 418–423
 51. Ruggles AJ, Ross MW, Freeman DE. Endoscopic examination and treatment of paranasal sinuses in 16 horses. *Vet Surg* 1993; 22: 508–514
 52. Galloway S. Equine oral photography. Notes from Am Assoc Eq Pract Dental Wet Lab 2008, Lexington, KY
 53. Wiggs RB, Lobprise HB. *Veterinary dentistry principles and practice*. Lippincott-Raven, Philadelphia, New York, 1997, p. 96
 54. Pence P. The dental examination. In: Pence P, ed. *Equine dentistry: a practical guide*. Lippincott, Williams and Wilkins, Philadelphia 2002, pp 53–78
 55. Floyd MR. The modified Triadan system: nomenclature for veterinary dentistry. *J Vet Dent* 1991; 4: 18
 56. Foster DL. Nomenclature for equine dental anatomy based on the modified Triadan system. *Proceedings, Annual Meeting of the International Association of Equine Dental Technicians*, Detroit, 1993, p. 35
 57. Klugh DO. Periodontal disease. In: *Current Therapy in Equine Medicine* 6. Robinson EN, ed. Sprayberry KA. Saunders, St Louis 2009, pp 328–334

Dental imaging

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Introduction

Imaging is an extremely important diagnostic tool for evaluation of equine dentition, particularly for those parts of the teeth and associated structures that cannot be evaluated during oral or endoscopic examinations. Radiography is still the most widely used and accessible diagnostic technique for veterinarians in general practice and the adoption of computed and direct digital radiography in many equine practices has undoubtedly resulted in improved image quality as compared with traditional film techniques. Radiography produces a two-dimensional image of a three-dimensional structure, and therefore, superimposition of the anatomically complex structures of the equine skull can present challenges to radiographic interpretation in some cases. In recent years, the use of three-dimensional imaging techniques, particularly computed tomography (CT), has become increasingly widespread. These techniques have led to significant improvement in our ability to accurately diagnose disorders of the equine dental structures and the anatomical regions that are closely associated with them, by their ability to produce high resolution images in multiple planes, and three-dimensional reconstructions of areas of interest, as seen later in this chapter. Magnetic resonance imaging (MRI) is most useful for investigation of soft tissue structures of the equine skull, and, in particular, the central nervous system; however, limitations in its ability to image structures containing mineralized material and gas mean that the technique is not ideal for dental imaging.

Scintigraphy reflects active physiological processes rather than the structural features portrayed by radiography, ultrasonography, CT, or MRI. The ability of scintigraphy, using ^{99m}Tc Technetium (^{99m}Tc) bound to phosphates, to detect bone remodeling before changes become radiographically apparent (because increased bone turnover usually precedes structural change) is one of the key advantages of this technique in the equine patient. The main application of scintigraphy in the equine upper respiratory tract is the investigation of potential periapical infection of the cheek teeth where it can often help differentiate between dental sinusitis and other causes of sinusitis.

Radiography

Radiographic techniques

Familiarity with correct radiographic techniques is probably the single most important factor in obtaining diagnostic quality radiographs of the equine skull and cheek teeth. The radiographic techniques described in this chapter are applicable to all equine practice situations, because portable radiography machines are adequate for obtaining all radiographic projections of the equine teeth. Exposure requirements are not high for equine dental radiography, especially if cassettes with rare-earth intensifying screens are used. Excellent quality radiographs can be obtained in the standing, heavily sedated horse, and consequently there is no requirement for general anesthesia.

Equipment

X-ray machines

Both portable and gantry-mounted machines can be used to obtain X-rays of the equine skull. It is extremely useful if the X-ray machine can be moved through a range of angles in three dimensions in order to allow the user to more readily obtain accurately positioned, oblique radiographs in standing horses; however, movement in two dimensions is adequate. It is also advantageous (but not essential) if the light beam diaphragm can be rotated to allow collimation of the primary beam in any direction, because the horse's skull is usually not aligned in a truly horizontal or vertical position.

Radiation safety

Radiation safety should be strictly adhered to when taking equine head radiographs, because personnel holding the horse and the cassette are potentially close to the primary beam. The primary beam should be collimated to include only the areas of interest, and the hands of personnel should be kept as far as possible from it. All assisting personnel should wear lead aprons, lead gloves, and radiation exposure badges (dosemeters), and should maintain a distance of at

least 1 m and preferably 2 m from the primary beam. If staff are required to hold horses or cassettes for radiography on a regular basis, consideration should be given to providing them with extremity dosimeters and thyroid guards. Heavy sedation of the horse reduces head movement and thereby reduces the need for repeat exposures due to movement artefacts.

Patient preparation

Most horses require sedation in order to obtain diagnostic radiographs of the skull due to the requirement to have both the cassette and X-ray tube in close proximity to their head. Heavy sedation (such as with xylazine, detomidine, or romifidine plus butorphanol) reduces head movement and facilitates the radiographic examination. Resting the nose of the horse on a stool or headstand may also help to minimize swaying movements caused by heavy sedation. A fabric (rope or webbing) head collar without metal components should be used during radiography of the equine skull. However, even a rope headcollar can create artefacts on a radiograph, and if possible, it should be moved out of the area of interest.

Occasionally, dental radiographs must be performed with the horse anesthetized, most commonly for intra-operative radiographs during cheek tooth repulsion or removal of radio-opaque tissues (e.g., cementomas, dystrophic mineralization, tooth root fragments, odontogenic tumors) from the sinuses or nasal cavity.

Imaging systems

Most equine veterinary practices now use cassettes with rare-earth ('fast') intensifying screens. These require a lower exposure but produce images with less detail than 'slow' screens, which contain calcium tungstate. In equine skull radiography, the risk of movement blur is high; therefore, a fast film-screen combination is preferred. In general, the film type must match the screen being used. The use of large (35 × 43 cm) cassettes is very helpful when evaluating a complex structure such as the equine head. This allows the entire cheek teeth row plus all adjacent structures of clinical significance to be included in the radiograph. Hence, the position of any observed abnormality can be assessed in relation to obvious anatomical landmarks. Specific equipment for intra-oral radiography of the cheek teeth is discussed in that section.

Computed radiography systems are rapidly superseding conventional film-based imaging systems in equine practice. In indirect computed radiography systems, cassettes contain phosphor screens (but no film) and are available in the same range of sizes as conventional cassettes. The latent image produced by X-rays is held within the screen until scanned by a laser. The images are similar in quality to the best film images, but have the advantage that they can be manipulated to adjust factors, such as brightness, contrast, and magnification, which can markedly improve their diagnostic usefulness. The vast majority of radiographic images in this chapter were produced on such a computed radiography system. Alternatively, direct digital radiography systems produce images immediately without a processing stage, and the image quality is superior to that of indirect computed

Table 13.1 Suggested exposures for various radiographic projections of the equine skull. Exposures have to be altered for different X-ray machines, different film-screen combinations, and varying size of patient

Region	Projection (s)		kV	mAs
Incisors/canines	Intra-oral	Pony	50	5
		TB	52	6
Incisors/canines	Lateral	Pony	55	6.3
		TB	60	6.3
Sinus	Lateral, Lateral oblique	Pony	60	6.3
		TB	63	6.3
Maxillary cheek teeth apices	Lateral, Lateral oblique	Pony	63	6.3
		TB	66	8
Mandibular cheek teeth apices	Lateral, Lateral oblique	Pony	66	6.3
		TB	66	8
Skull	Dorsoventral	Pony	70	8
		TB	73	8
Cheek teeth occlusal aspects	Open-mouthed oblique	Pony	60	6.3
		TB	63	6.3

TB = Thoroughbred-type horse.

radiography. Other than slight modifications in exposure values, the technique of acquiring radiographic views and the ancillary equipment required are the same regardless of which radiographic system is used.

Exposures

The choice of exposure factors depends on the output of the X-ray machine and speed of the imaging system in use.¹ Table 13.1 gives examples of exposures suitable for obtaining dental and sinus radiographs.

Accessory equipment

Grids

The use of grids is discouraged for standing radiography as they are not required for obtaining high quality radiographs, because the amount of scattered radiation is usually minimal, and their use increases the risk of radiation exposure to personnel. Additionally, for oblique views, it may be difficult to accurately align and center the X-ray beam with the grid, which may result in image artefacts.

Cassette holders

The use of cassette holders is essential in order to minimize exposure of personnel to the primary beam, and holding cassettes by hand should be considered unacceptable. A flexible and readily adjustable system is required to allow radiography of different sized horses and varying resting head positions. This is most easily achieved using a long-handled cassette holder, which can be constructed from wood or aluminum, with a handle up to 2 m long and which can be



Fig. 13.1 Use of a long-handled cassette holder to increase the distance between personnel and the primary beam. Note the horse is wearing a rope headcollar.

adjusted to different heights and varying angulations (Fig. 13.1). Alternatively, vertical suspension systems linked to the X-ray tube are also suitable for lateral or latero-oblique radiographic views, as is simply suspending the cassette in a fabric bag (e.g., pillowcase) hanging from a mobile (e.g., drip) stand. Long adjustable ties at each side of the bag allow varying heights and angles of the cassette to be obtained.¹

Radiographic projections

Introduction

Indications for equine dental radiography are numerous but most commonly include clinical signs associated with periapical dental disease, including disorders of the paranasal sinuses or nasal cavities (unilateral nasal discharge, facial or mandibular swellings, quidding, discharging sinus tracts), head trauma, developmental abnormalities, or periodontal disease. Various radiographic projections and techniques have been reported,¹⁻⁷ but the 'standard' set of radiographs required to investigate a clinical case depends on the individual case presentation, clinician preference, and hospital protocols. In the author's (SB) hospital, lateral, lateral oblique and dorsoventral radiographs are considered standard for investigation of a horse with suspected maxillary cheek tooth periapical infection and concurrent sinusitis. For suspected mandibular cheek tooth periapical infection, a lateral oblique view, plus the same view with a radio-opaque marker placed on the clinical area of interest (swelling or draining tract), usually suffices. In some cases, additional views, such as open-mouthed, intra-oral, or lesion-orientated obliques are useful. Practical tips for dental/skull radiography are given in Box 13.1.

Incisors and canines

Intra-oral radiographs (Fig 13.2)

The smallest cassette available should be used, and the patient must be sedated to prevent damage to the cassette. A low exposure is required compared with that needed to

Box 13.1 Practical tips for dental/skull radiography

- Using a large cassette and collimating the primary beam to include a large area, e.g., the entire maxillary cheek teeth row and sinuses if a maxillary dental disorder is suspected, can make interpretation of skull radiographs easier as abnormalities can be related to easily identifiable anatomical structures
- Resting the nose of a deeply sedated horse on a stool or headstand may help to reduce swaying movements of the head
- Attaching the cassette directly to the head using bungee type elastic cords is an alternative way to prevent movement blur and removes the need for a second person to hold the cassette holder
- Using a lower exposure to view the paranasal sinus contents, incisors or wolf teeth, as compared with the relatively radio-opaque cheek teeth
- Using a small radio-opaque marker taped on an area of facial swelling or a blunt probe passed into a draining tract can provide invaluable information regarding the significance of radiological findings (see 'Contrast studies')
- Radiograph the contralateral (unaffected) cheek teeth row if you have difficulty deciding if a suspected abnormality is pathological or physiological (see 'Normal radiographic anatomy')

image the cheek teeth. The cassette should be placed between the incisors, as far caudally as possible, and held in position using long-handled hoof trimmer testers or a similar instrument, with the cassette held at a distance from the assistant.¹ The X-ray beam is directed at 60–80° from the dorsal plane (which runs parallel to the hard palate), depending on the conformation of the incisors, using a rostradorsal–caudoventral oblique to image the maxillary incisors/canines and a rostroventral–caudodorsal oblique to image the mandibular incisors/canines. The beam should be centered on the Triadan 01s (central incisors), and collimation should include the rostral and lateral aspects of the lips. If necessary, the X-ray beam can also be angulated slightly from left to right to try and highlight the apices of incisors at the edges of the incisor arcade without superimposition of adjacent teeth (Figs 13.3 & 13.4).

Lateral projections

These radiographs are occasionally indicated, although the superimposition of incisors of the right and left sides usually makes individual incisors impossible to distinguish. They can be useful for identification and orientation of dysplastic or retained incisors or for assessment of fractures of the premaxilla or rostral mandible. Adding a slight (5–10°) rostrocaudal angulation to a lateral radiograph centered on the canines can provide separation of left and right sides and allow examination of individual reserve crowns and apices of these teeth.

Canines and wolf teeth

Lateral oblique projections

All or part of the canines may be visible on intra-oral films (see previous section), but in many horses the reserve crown and roots of the canines, as well as the wolf teeth (Triadan 05s, 1st premolars), are best imaged using a lateral

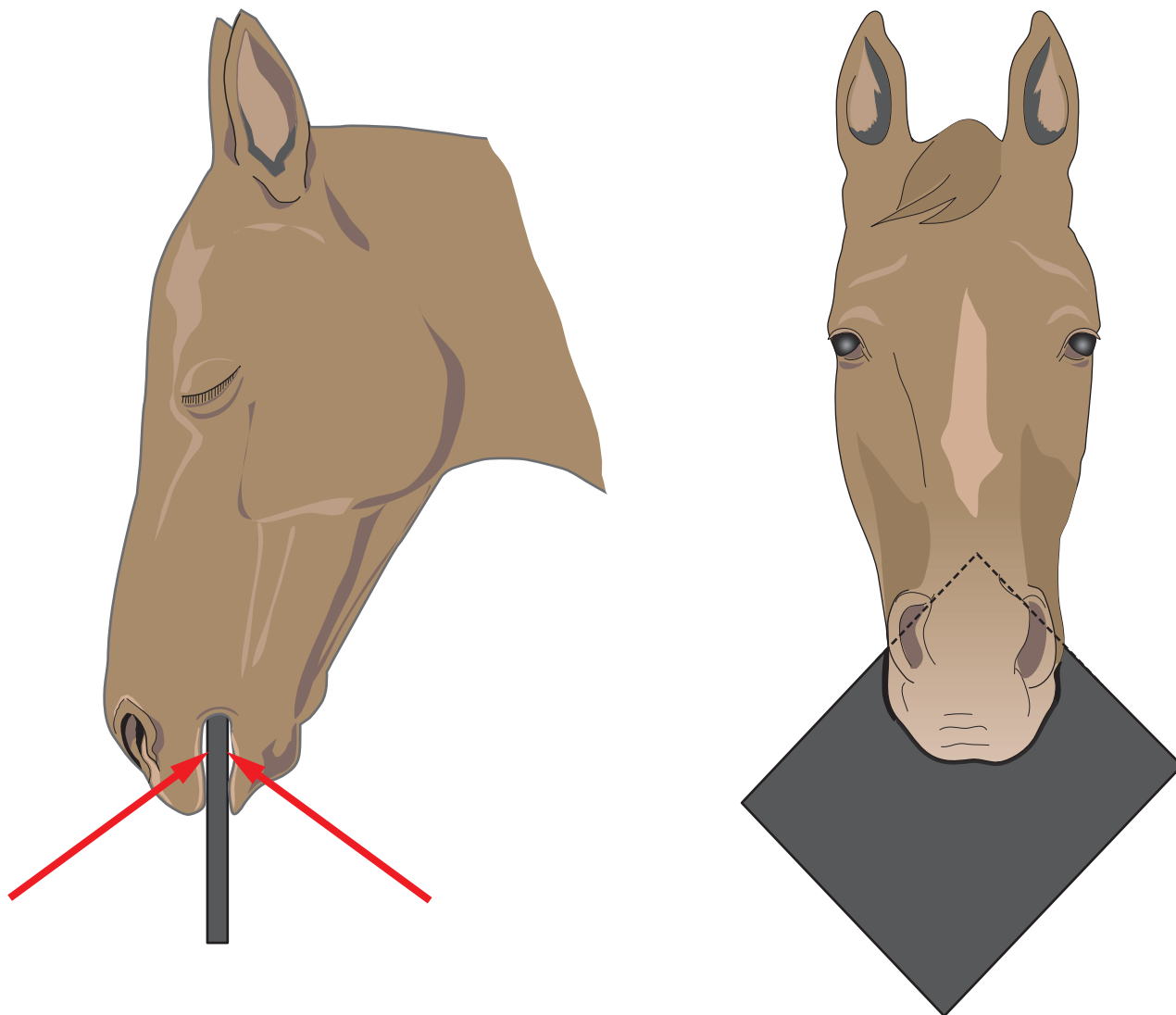


Fig. 13.2 Cassette and X-ray beam positioning for intra-oral projections of the incisors and canine teeth.



Fig. 13.3 Intra-oral view of the lower incisors of a horse with abnormally small and fractured 01s and 02s. This radiograph was taken with the X-ray beam perpendicular to the frontal plane. Note there is superimposition of the apices of the 02s, 03s and canines.



Fig. 13.4 Intra-oral view of the same horse as in Fig. 13.3. The radiograph is taken at a slight angle (25°) to the frontal plane from left to right. Note that on the right side of the radiograph, the apices of 302 and 303 are no longer superimposed.

projection of the rostral skull with a small amount ($15\text{--}20^\circ$) of either rostrocaudal or dorsoventral angulation of the X-ray beam. The angulation prevents superimposition of the contralateral tooth.

Cheek teeth

Lateral projection (Figs 13.5–13.7)

The lateral view is useful to visualize fluid lines and abnormalities of the maxillary or frontal bones or within the paranasal sinuses because the anatomy of the sinuses is not distorted by obliquity of the X-ray beam. The major disadvantage of the lateral view is that lesions cannot be localized to the left or right sides because both sides are superimposed. For this same reason, individual cheek teeth apices cannot be evaluated using this view.

The horse should be positioned with the lesion side adjacent to the cassette. The cassette should be held in the cassette holder in a vertical plane, parallel with the dorsal contour of the head, and as close to the head as possible. The primary beam should be horizontal and perpendicular to the long axis of the head. The primary beam should be collimated to reduce scatter, and rotating the light beam diaphragm unit to align it with the orientation of the horse's skull helps to keep the collimation tight.

For maxillary cheek teeth, the beam should be centered just dorsal to the rostral aspect of the facial crest if the cheek teeth and/or paranasal sinuses are being examined. The entire facial area should be included to ensure that the entire maxillary cheek teeth row and all the paranasal sinuses are included in the radiograph. Hence, topographic markers for collimation include: the caudal aspect of the diastema ('bars of mouth') rostrally, the eye caudally, and the dorsal aspect of the skull (Fig. 13.6).

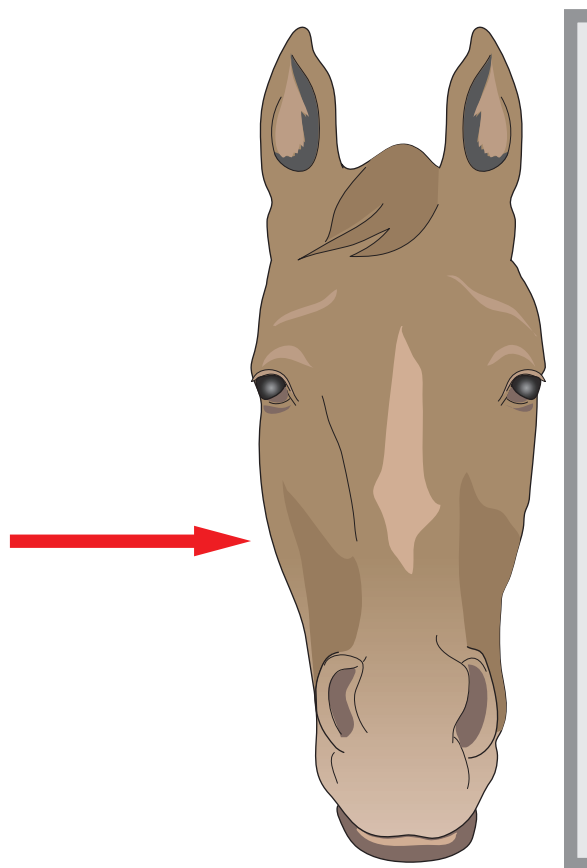


Fig. 13.5 Direction of the X-ray beam (arrow) and cassette position for lateral projections of the skull.

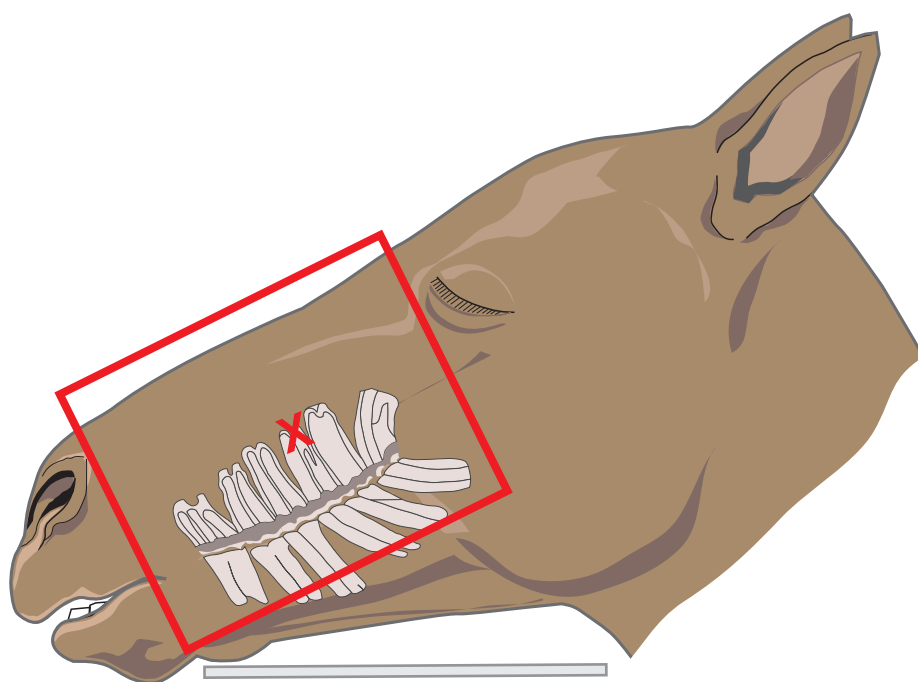


Fig. 13.6 Centering point (red cross) just dorsal to the rostral aspect of the facial crest and collimation (red outline) for lateral and lateral oblique radiographs of the maxillary cheek teeth and paranasal sinuses.

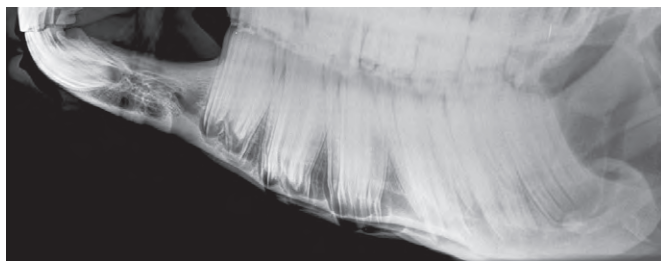


Fig. 13.7 Lateral radiograph of a normal mandibular cheek tooth row. Note that the soft tissue opacity of the thick masseter and pterygoideus muscles are superimposed over the caudal 3 cheek teeth.

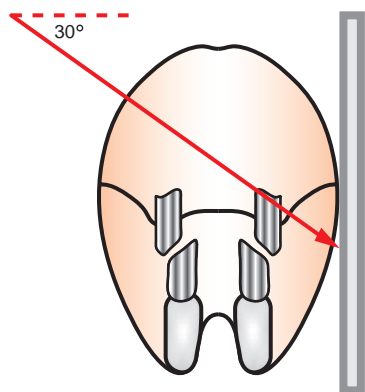


Fig. 13.8 Diagram showing direction of the X-ray beam (arrow) and cassette position for latero30°dorsal-lateroventral oblique radiograph of the maxillary cheek teeth apices.

Lateral views of the mandibular cheek teeth are less frequently indicated, but the beam should be centered over the area of interest (usually indicated by a discharging tract or mandibular swelling), and rostrocaudal collimation should be adjusted to include the entire cheek teeth row, if possible. The thick masseter and pterygoideus muscles overlie the caudal three mandibular cheek teeth (Fig. 13.7), and hence higher exposures are required to image the apices of these teeth as compared to the rostral mandibular cheek teeth.

Latero30°dorsal–lateroventral oblique projection (Figs 13.8–13.9)

This view separates structures on the left and right sides of the skull so that they are not superimposed on each other. It gives the clearest view of the apices of individual maxillary cheek teeth and can help to localize sinus lesions to the left or right sides if this is not clinically obvious. A higher exposure should be used to radiograph the radio-opaque cheek teeth as compared to the relatively radiolucent sinus contents.

Disadvantages of the oblique view are that it can be more difficult to consistently obtain good quality oblique radiographs, because the angulation of the standing sedated horse's head is usually somewhere between vertical and horizontal, making it difficult to direct the X-ray beam accurately. As noted, having an X-ray machine that can be moved in three dimensions helps enormously when obtaining these views. It should be noted that fluid lines in the sinuses are



Fig. 13.9 Radiographic positioning to obtain a latero30°dorsal-lateroventral oblique radiograph of the maxillary cheek teeth apices.

often not apparent in oblique views, being replaced with indistinct soft tissue opacity. Additionally, it can be more difficult to localize abnormalities to specific sinuses due to superimposition of some structures e.g., the dorsal aspect of the caudal maxillary sinus and the dorsal-conchal sinus are often superimposed.

The standing horse should be positioned so that the lesion side is next to the cassette, which is held in the cassette holder in a vertical plane, close to the horse's head. The primary beam should be angled latero30°dorsal-lateroventral (i.e., at 30° from the dorsal plane, which runs parallel to the hard palate) and centered 3–5 cm dorsal to the rostral aspect of the facial crest (Fig. 13.6).

The primary beam should be collimated to reduce scatter (as for the straight lateral view) and should include the entire maxillary cheek teeth row and the paranasal sinuses. Inadvertent rostrocaudal angulation of the X-ray beam is a common fault and should be avoided if possible. Excessive rostrocaudal (or dorsoventral) angulation distorts anatomical structures, particularly the apices of the cheek teeth, making them difficult to evaluate accurately.

For anesthetized horses, which are usually positioned in lateral recumbency with the affected side uppermost (to allow access for surgery), the cassette is placed beneath the horse's head, i.e., next to the unaffected side, rather than next to the affected side as is the case for standing horses. Therefore the angle of the X-ray beam must be *reversed* (compared to the standing horse) to obtain oblique projections of the cheek teeth or sinuses, e.g., for maxillary cheek teeth apices with the affected side uppermost, a ventrolateral to dorsolateral beam direction is required (Fig. 13.10). This projection creates more magnification of the image but should not have a deleterious effect on surgical decision-making unless measurements for surgical implants (e.g., dynamic compression plates) are being made. In such cases, placing a metal marker of known size in the region of interest allows for calculation of the degree of magnification and subsequent correction.

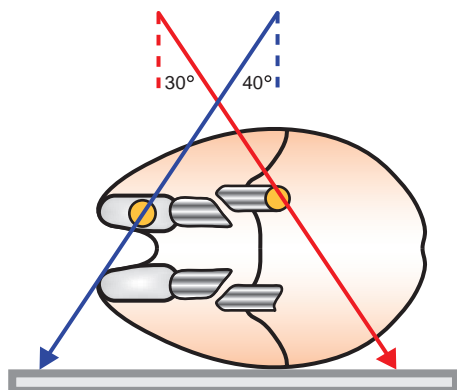


Fig. 13.10 Lateral oblique radiographic projections of the maxillary (red arrow) and mandibular (blue arrow) cheek tooth apices in an anesthetized, laterally recumbent horse undergoing surgery. The affected side is placed uppermost to allow surgical access to the lesion (orange circles), and the cassette is placed underneath the head. The X-ray beam must be directed in the opposite direction to conventional views, and more magnification of the image results.

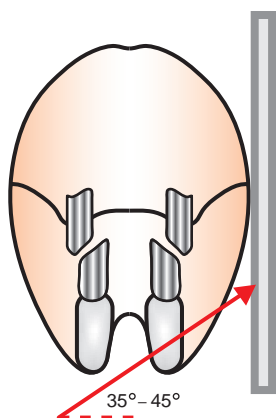


Fig. 13.11 Positioning of cassette and angle of X-ray beam to obtain a latero35–45° ventral–laterodorsal oblique radiograph of the mandibular cortex and cheek teeth apices.

Latero35–45° ventral–laterodorsal oblique projections (Fig. 13.11)

This view is used to separate the left and right hemimandibles and mandibular cheek teeth apices in order to view the affected side without superimposition of the contralateral hemimandible. As previously noted, a higher exposure is required when imaging the caudal three cheek teeth because of the overlying thick masseter and pterygoideus muscles (Fig. 13.7). Additionally, a higher angle is usually required for radiography of the caudal cheek teeth apices because these are positioned more dorsally within the mandibular bone. For the same reason, the cheek teeth of old horses with short reserve crowns also need to be radiographed using a higher angle.

Similar to the latero30° dorsal–lateroventral oblique view, inadvertent rostrocaudal angulation of the X-ray beam is a common fault with this view of the mandible, and should be avoided, if possible, because excessive rostrocaudal angulation distorts anatomical structures, particularly the apices

of the cheek teeth, making them difficult to evaluate accurately. The minimum dorsoventral angle of X-ray beam which clearly separates the left and right cheek teeth apices should be used. Using a very large oblique angle gives better separation of the cheek teeth rows and allows visualization of more reserve crown, but also causes artefactual distortion of the apices.

The standing horse should be positioned so that the lesion side is closest to the cassette, which is held in the cassette holder in a vertical plane. The primary beam should be angled 35–45° lateroventral–laterodorsal (angled up from the dorsal plane which runs parallel with the hard palate) and centered at the area of interest, such as a mandibular swelling or cutaneous discharging tract – whose presence is the usual indication for taking this radiographic view. The primary beam should be collimated to reduce scatter but should include the ventral mandibular cortex and the entire cheek teeth row, if possible.

For anesthetized horses, which are usually positioned in lateral recumbency with the affected side uppermost (to allow access for surgery), the cassette is placed beneath the horse's head i.e., next to the unaffected side, and the direction of the X-ray beam is reversed (Fig. 13.10).

Dorsoventral projection (Figs 13.12–13.13)

This view is quite easy to obtain in the sedated horse and is particularly useful for visualizing the ventral conchal sinus, nasal cavities, and nasal septum. Additionally, it can be used for evaluating maxillary/mandibular fractures; bony distortion of the maxilla associated with periapical infection of the rostral cheek teeth or intra-sinus masses. Laterally or medially displaced teeth and fractured maxillary teeth (particularly sagittal fractures) can also be visualized with this view; however, these abnormalities should be apparent during a thorough oral examination. The extremely dense bone of the hemimandibles makes it almost impossible to evaluate normally positioned mandibular cheek teeth using this projection.

An increased exposure is required for this projection compared to those used for lateral or lateral-oblique views of the skull. The X-ray beam is directed perpendicular to the dorsal plane of the head (which runs parallel to the hard palate) with the cassette held parallel with the ventral mandible and positioned as caudally as possible (Fig. 13.12). Because the mandibular cheek teeth rows are so close together (anisognathia), even a small degree of obliquity obscures one nasal cavity, ventral conchal sinus, and maxillary cheek teeth row and prevents accurate comparison of left and right maxillary sinus opacity; therefore, great care must be taken to ensure that the head is absolutely straight and the beam perpendicular to the dorsal plane. The centering point is in the midline of the dorsal aspect of the head at the level of the rostral aspect of the facial crests. Collimation of the primary beam should include the left and right lateral extents of the skull, the caudal aspects of the bony orbits and the diastemata, rostrally (Fig. 13.13).

In the anesthetized horse, ventrodorsal radiographs can be obtained with the horse positioned in dorsal recumbency and the head and neck fully extended. Ideally, the endotracheal tube should be removed to prevent its superimposition on the nasal cavities and conchal sinuses.

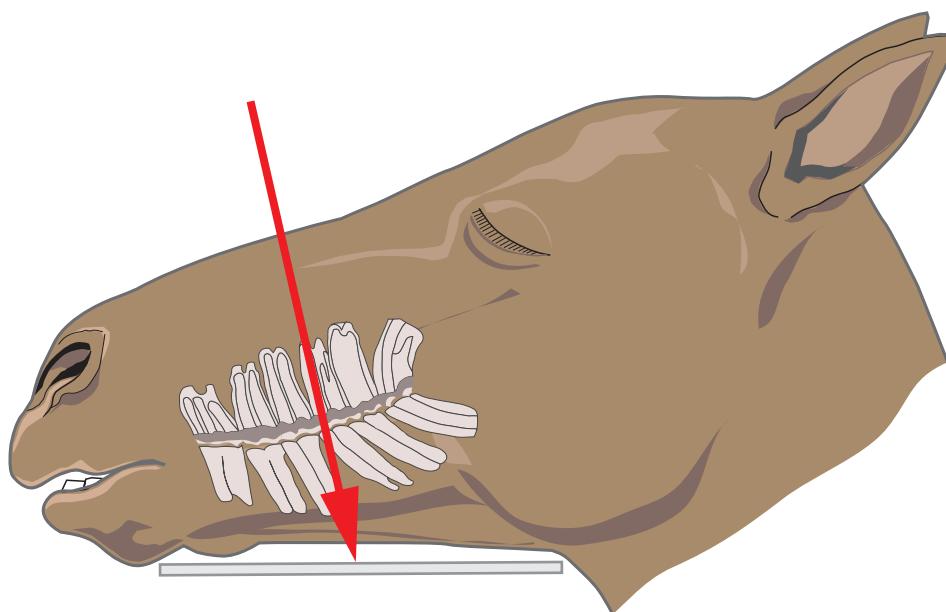


Fig. 13.12 Diagram showing cassette position and angle of the X-ray beam for obtaining a dorsoventral radiograph of the skull.

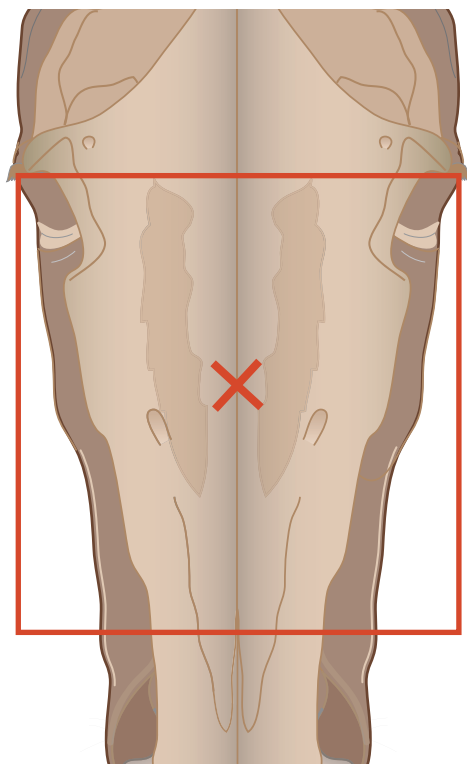


Fig. 13.13 Diagram showing area of collimation and centering point (cross, at the level of the rostral aspect of the facial crests) for dorsoventral radiographs of the skull.

Dorsoventral projection with offset mandible

This radiographic projection is uncommonly indicated, but gives a clearer unilateral view of the medial aspect of one row of maxillary cheek teeth and the nasal cavity/conchal sinus immediately axial to them. It has been suggested that this projection is particularly useful for demonstrating subtle



Fig. 13.14 Photograph showing sedated patient with a Butler's gag separating the incisors to allow an open-mouthed oblique dental radiograph to be obtained.

alveolar disease and maxillary osteitis.¹ A rope is placed around the interdental space, and the mandible is displaced to the contralateral side by an assistant pulling on this rope. A dorsoventral projection is then obtained as described above.

Open-mouthed oblique projections (Figs 13.14–13.18)

This radiographic view is used to image the erupted crowns of the cheek teeth and the occlusal aspect of the alveolus (alveolar crest).⁶ Disorders of the erupted crown such as diastemata, clinical crown fractures, and abnormalities of wear can be imaged.⁶ The patient must be sedated so that it accepts a Butler's gag placed between its incisors (Fig. 13.14).

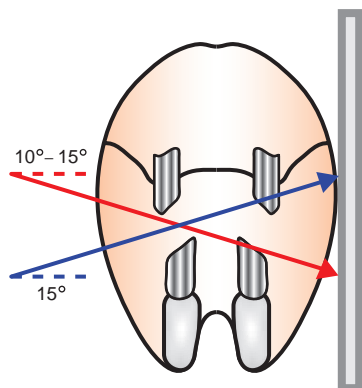


Fig. 13.15 Diagram showing angle of incidence of the X-ray beam to obtain open-mouthed oblique views of the maxillary (blue arrow) and mandibular (red arrow) erupted crowns. The affected side is nearest to the cassette.

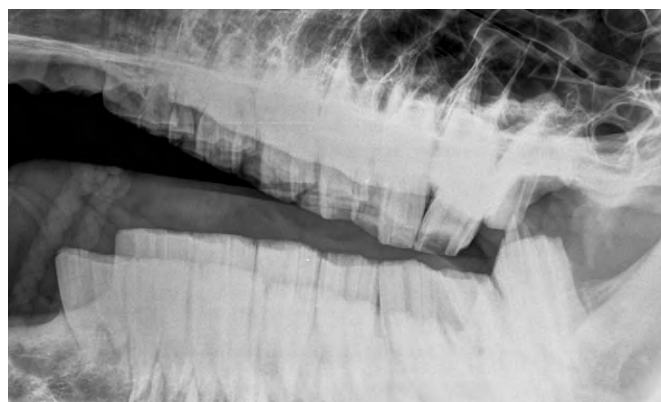


Fig. 13.16 Latero10°ventral-laterodorsal open-mouthed oblique view of an aged horse with a supernumerary mandibular cheek tooth (Triadan 12). Note the large overgrowths present on this supernumerary tooth and the excessive wear of the corresponding upper 11.

Alternatively a short length of hollow PVC tubing or a block of wood can be used to separate the incisors and thus the occlusal aspects of the cheek teeth.

The cassette is positioned vertically on the lesion side, close to horse's head. For these open-mouth views, the X-ray beam is directed in the opposite direction to conventional (closed mouth) oblique views i.e., a dorsolateral-ventrolateral to image the mandibular erupted crowns or a ventrolateral-dorsolateral to image the maxillary erupted crowns. Additionally, the angle of incidence of the X-ray beam is reduced compared to conventional oblique views: latero10°dorsal-lateroventral (ventrally) for mandibular cheek teeth, latero15°ventral-laterodorsal (dorsally) for maxillary cheek teeth. The primary beam should be centered on the rostral aspect of the facial crest and collimated to include all the erupted crowns in the cheek teeth row (Fig. 13.16).

To image the full length of the cheek teeth reserve crowns, open-mouthed oblique projections using approximately the same angles as for standard closed-mouth views may be used, although to prevent superimposition of the contralateral maxillary arcade completely, laterodorsal angles slightly greater than 30° may be required. These projections are also



Fig. 13.17 Open-mouthed oblique view centered on the 05s (wolf teeth) showing large, rostrally displaced and abnormally angulated upper 05s with long thin roots. The Butler's gag is separating the incisors.

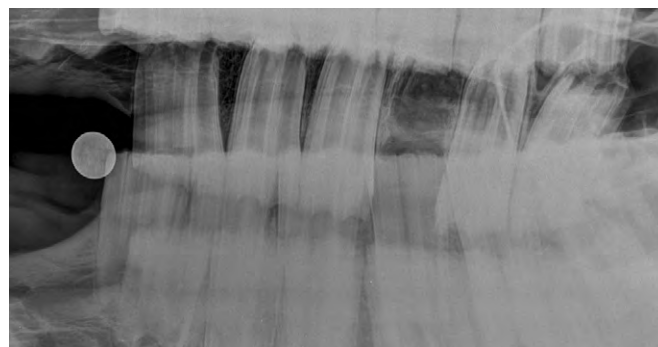


Fig. 13.18 Latero30°ventral-laterodorsal open-mouthed oblique view of a horse immediately after 09 dental extraction. The contents of the mid and more occlusal aspects of the empty alveolus can be visualized without superimposition from cheek teeth of the contralateral row.

often helpful for examining alveoli for possible dental fragments after dental repulsion (Fig. 13.18). Open-mouthed oblique projections are also useful for imaging the Triadan 05s (wolf teeth) (Fig. 13.17).

Intra-oral oblique projections (Figs 13.19–13.20)

These projections, where a flexible film package or cassette is placed into the oral cavity, represent a modification of the bisecting angle technique used widely in human dental imaging. They have the advantages that there is no superimposition of structures from the contralateral side of the skull, and can also give good detail of the interdental bone and alveolar crest region. However, in the author's experience, these projections can be difficult to obtain in standing sedated horses, due to difficulties keeping the film in place within the oral cavity.

The use of human dental film packs⁴ or of improvised cassettes made of vinyl⁷ or heavy-duty black polythene¹ has been described for intra-oral projections in horses. Pre-packed human dental film is often only large enough to image one or two cheek teeth on each radiograph, and this is a major disadvantage, particularly because the affected tooth is not commonly identified prior to the radiographic examination. Improvised cassettes can be made into a suitable shape for the equine oral cavity (circa 10 × 25 cm) by

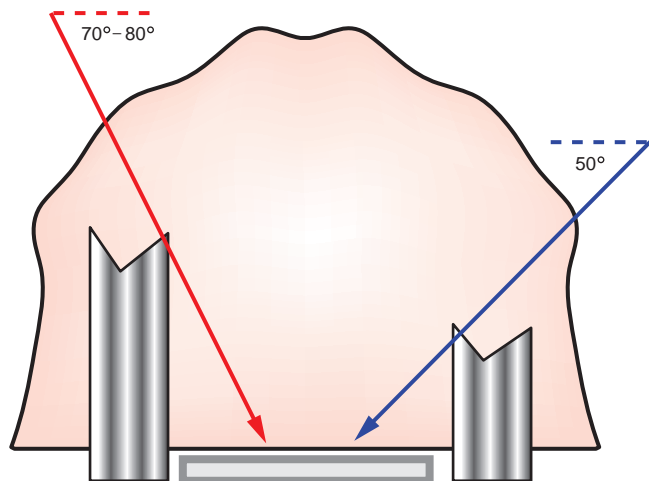


Fig. 13.19 Diagram showing intra-oral position of the cassette and angles of incidence of the X-ray beam to obtain intra-oral cheek teeth radiographs of young horses with long reserve crowns (left) and older horses (right).

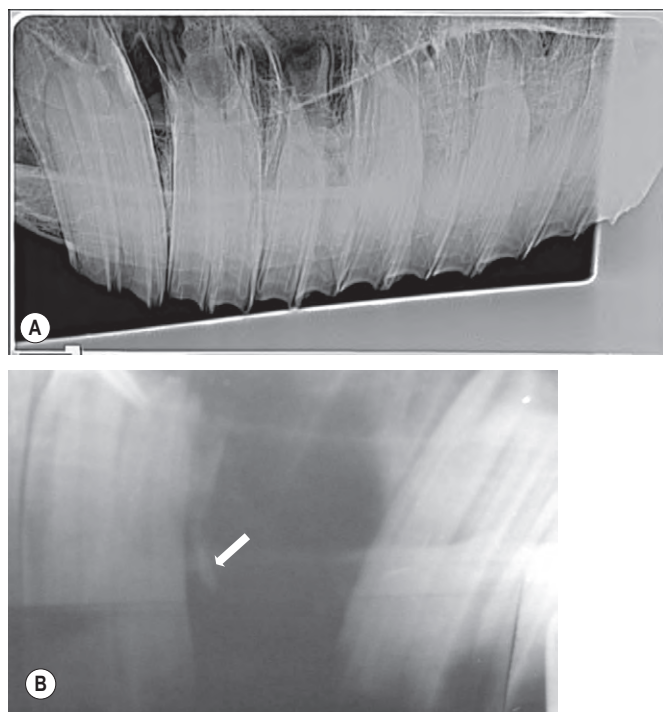


Fig. 13.20 (A) Intra-oral radiograph of a maxillary cheek teeth row. Radiograph courtesy of J. Easley. (B) Intra-oral radiograph taken intra-operatively during a dental extraction procedure. A small bone-opacity fragment can be seen in the rostral aspect of the alveolus (arrow). (Radiograph courtesy of W.H. Tremaine.)

cutting down film and card-mounted intensifying screen(s) before double wrapping them in closely fitting, light-proof bags e.g., of heavy-duty black polythene, and sealing the edges with light-proof adhesive tape.¹ The disadvantages of this system include the time taken to prepare the above materials, poor film/screen contact and the need for wet processing of films.

A self-retaining, full-mouth speculum is used to open the mouth of the heavily sedated or anesthetized horse, and the

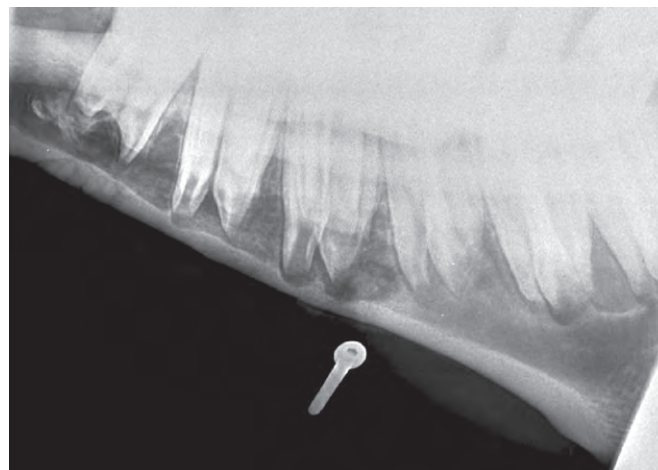


Fig. 13.21 Lateral oblique radiograph of the hemimandible of a horse which presented with a swelling on the ventral aspect of its mandible. A radio-opaque marker has been taped to the area of maximal facial swelling, which corresponds to an area of clubbing (short, rounded appearance) of the caudal root of the 08 due to loss of the apex of that root and surrounding radiolucency.

film is placed in the oral cavity, parallel to the hard palate (Fig. 13.19). If using a small sized film, it must be placed at the level of the tooth of interest. For teeth of mature or older horses, the X-ray beam is directed at an angle of 50°–60° to the horizontal, but to examine the longer reserve crowns of young horses, increased incident angles (70°–80°) are required (Fig. 13.19). The centering point is somewhere between the level of the facial crest and up to 6 cm dorsal to the facial crest, depending on the length of the tooth being radiographed i.e., in younger horses, a more dorsal centering point is required compared to aged horses with short reserve crowns.

Contrast studies

Placement of a radio-opaque marker over an area of facial swelling and repetition of a radiographic projection (Fig. 13.21) can be an invaluable aid when assessing the clinical significance of radiographic changes. If a cutaneous draining tract is present, as is common in cases of periapical infection of the mandibular cheek teeth or upper 06s and 07s, a blunt metallic probe can be placed into the tract, held in place with tape (Fig. 13.22) and a repeat radiograph taken (Fig. 13.23). This very simple form of contrast study often provides unequivocal evidence that a tooth is infected.

Water soluble iodinated contrast media may also be introduced into a tract i.e., fistulography. To avoid leakage, injection should be made through a self-retaining catheter with an inflatable bulb (e.g., Foley) and discontinued immediately resistance is felt.¹

Normal radiographic anatomy

Deciduous dentition

Deciduous incisors are more radiolucent, have shorter reserve crowns and roots, and have a smaller cross-sectional area than their permanent counterparts (Fig. 13.24).

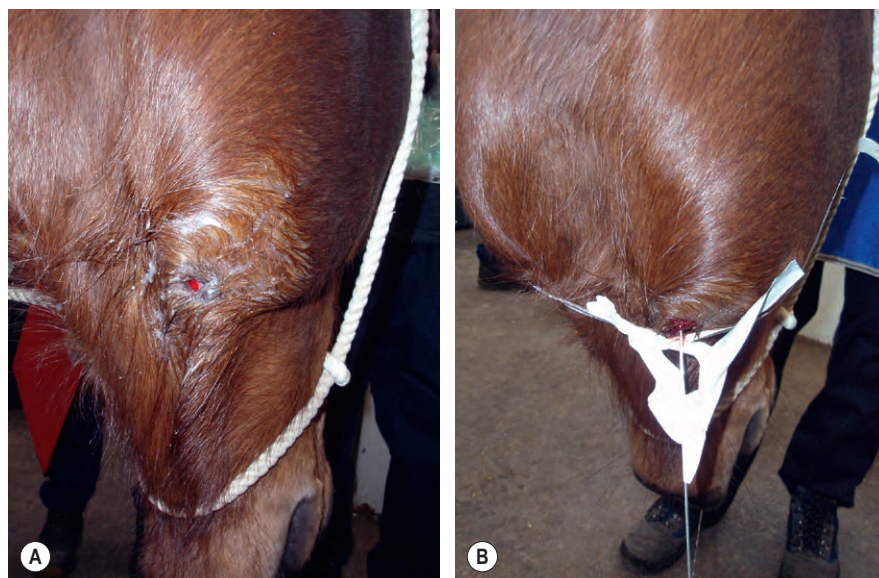


Fig. 13.22 (A & B) A blunt metallic probe placed into a cutaneous discharging tract and secured with radiolucent tape can provide strong evidence as to which tooth is infected in cases of suspected periapical infection.

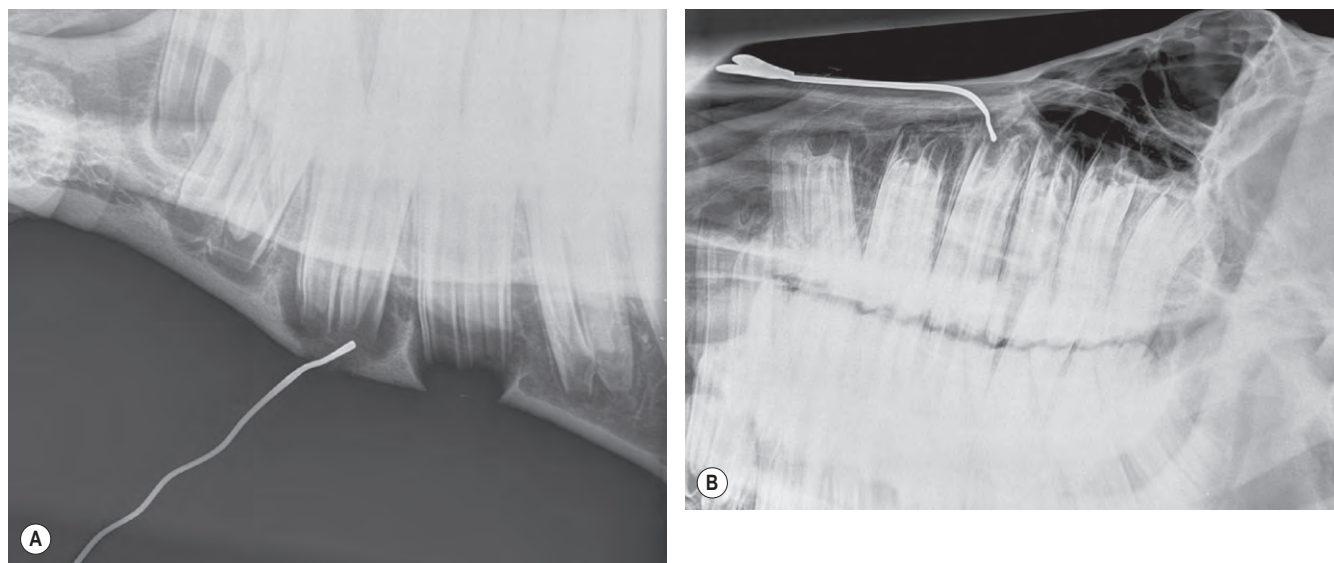


Fig. 13.23 Lateral oblique radiographs with a blunt metallic probe in place in cases of periapical infection with discharging cutaneous tracts involving the mandibular (A) and rostral maxillary (B) cheek teeth.

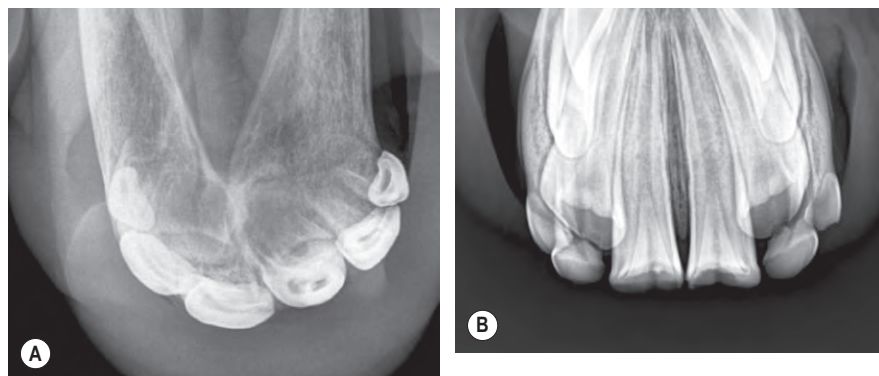


Fig. 13.24 Intra-oral radiographs of the mandibular incisors of: (A) a yearling with a fractured mandible (note the obliquity of the left incisors compared to the right). The developing buds of the permanent 301 and 401 can be seen mesial to the 701 and 801. (B) A 3-year-old horse. The 301 and 401 (central incisors) are erupted but the deciduous lower 02s and 03s remain in wear. Note the canines are superimposed on the developing permanent 03s.



Fig. 13.25 Lateral oblique view of a foal's skull. Note the short spicular roots of the 3 deciduous cheek teeth in each row. The dental buds of the permanent cheek teeth are not apparent yet.

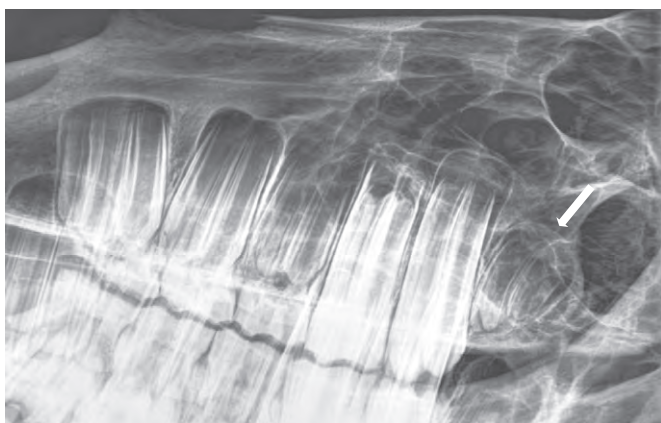


Fig. 13.26 Lateral oblique radiograph of the maxillary cheek teeth of a 2-year-old horse. The 09 has erupted and is in wear, and the 10 is just erupting. The dental buds of the permanent 06, 07, and 08 can be seen developing dorsal to their deciduous counterparts, with the deciduous 06 about to be shed. The dental bud of the 11 (arrow) is developing at the caudal aspect of the maxilla.

Deciduous canines (if present) are vestigial, spicule-like structures that do not erupt above gum level, but which are occasionally evident radiographically.

Linear, radio-opaque enamel folds may be seen within the developing deciduous cheek teeth of the fetus, and soon after birth foals should have 12 deciduous cheek teeth present in the oral cavity. These teeth have short, spicular roots (Fig. 13.25) and can be distinguished from developing permanent premolars by their greater mineral content and relative lack of internal structure.¹ As the germs of the permanent cheek teeth develop beneath the deciduous cheek teeth (Fig. 13.26), they cause resorption of the apices of their overlying deciduous counterparts.⁸

Permanent dentition

Incisors, canines and wolf teeth

The reserve crowns and apices of the permanent incisors converge towards each other on an intra-oral radiographic projection, and there may be partial superimposition of the reserve crowns and roots of the Triadan 02s and 03s (middle and corner incisors) on a true dorsoventral radiograph (Fig. 13.27). If the roots and reserve crowns of these teeth are to be examined in detail, a slight angulation of the X-ray

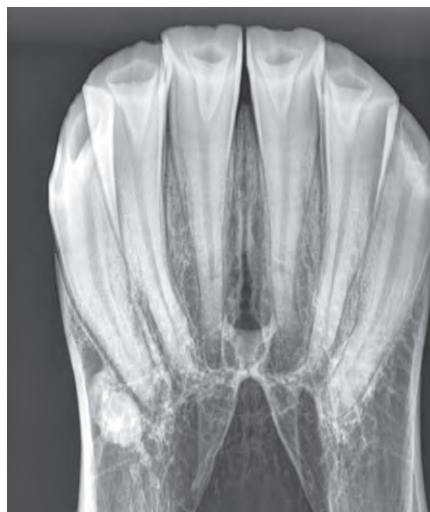


Fig. 13.27 Intra-oral radiograph of the rostral mandible of a teenage horse. Note the triangular cross section of the occlusal surfaces of the 01s and 02s (central and middle incisors) as compared to those of a young horse (Fig. 13.24). There is a vestigial dental remnant lying just caudal to 303.

beam can be used to prevent this superimposition (Fig. 13.4). The incisor teeth gradually change their angle throughout life, the occlusal angles changing from almost vertical in a young horse to an increasing angle of incidence, and the occlusal surface becomes more triangular in cross section with advancing age. In recently erupted incisors, the infundibula can be recognized on the obliquely projected occlusal surfaces and in those that have been longer in wear, traces of infundibular enamel and cement may be visible as thin, elliptical conical radiodense shadows.¹ The pulp cavities of the incisors should be evident as curvilinear radiolucent structures in the middle of these teeth.

The canine teeth, and particularly the lower canines, are positioned in close proximity to the 03s (Fig. 13.24B) and it may be difficult to clearly delineate the roots and reserve crowns of the canines due to superimposition of the roots and reserve crowns of the 03s (the corner incisors) in some horses. Small unerupted canines may be present below the gingiva in mares. If present, the 05s ('wolf teeth', Fig. 13.18) are normally situated immediately rostral to the 06s (1st cheek tooth). Up to 4 wolf teeth may be present; however, mandibular 05s are very rare. Wolf teeth may vary markedly in the size of their clinical crown, and the roots of these brachydont teeth can vary from a few mm to >2 cm in length. In a survey of radiographs of 134 horses, wolf teeth were present in 30 % of horses, but this may not be a true reflection of their incidence due to the common practice of 'prophylactic' or 'therapeutic' removal.⁹

Cheek teeth

The radiographic appearance of equine cheek teeth, and particularly their apices, varies markedly with age, and between individual cheek teeth positions. Consequently an appreciation of normal radiographic variation is required to enable proper interpretation of dental radiographs. Most apical infections occur in young horses where there can be marked differences in the radiographic appearance of the

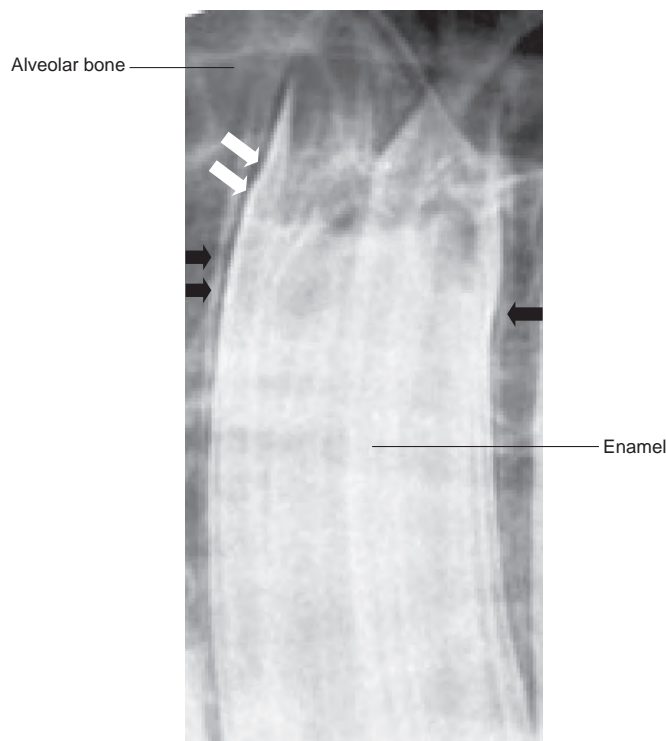


Fig. 13.28 Close up X-ray of a maxillary cheek tooth. The lamina dura (black arrows) is a linear radio-opacity that lines the alveolus. Note that the lamina dura denta is not visible along the entire contour of this normal tooth. The periodontal ligament (white arrows) is represented by a radiolucent area between the lamina dura and the periphery of the tooth.

apical areas of normal adjacent teeth, and where immature apices with eruption cysts can radiographically resemble apical infections.

Enamel, dentin, and cementum (along with bone) are the densest materials in the body, and therefore the cheek teeth appear as very radio-opaque structures, within which the radiolucent pulp horns may be seen running longitudinally. Dentin and cementum have a lower proportion of mineral content than enamel and have a radio-opacity similar to bone.² Younger cheek teeth contain little dentin relative to aged cheek teeth, and are, therefore, comparatively radiolucent.² The reserve crown of the cheek teeth is attached to the alveolar bone by the periodontal ligament, which is evident radiographically as a narrow parallel radiolucent line between the tooth and the alveolus (Fig. 13.28). This space lies adjacent to a radiodense rim of cortical alveolar bone, radiographically, termed the *lamina dura*, which lines the alveolus (Fig. 13-28). Although disruption of this structure can occur with dental disease, the irregular contour of equine cheek teeth means that the *lamina dura* may not be visible on some radiographic projections of normal teeth, and (in contrast to brachydont radiographs) absence or partial discontinuity of the *lamina dura* is not a reliable indicator of apical or periodontal disease.^{9,10} The area of the periodontal ligament may widen due to disease processes, but the apices of young equine cheek teeth also have wider radiolucent areas adjacent to the *lamina dura* in the area of the eruption cysts (Fig. 13.29).

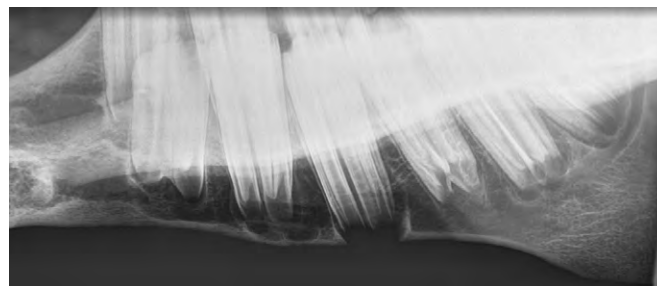


Fig. 13.29 Lateral oblique radiograph of the hemimandible of a normal 3-year-old horse. Note the wide, rounded, radiolucent periapical regions of the 07 and 08 which are termed 'eruption cysts'. The ventral cortex of the mandible beneath the 08 is convex and extremely thin and appears radiolucent.

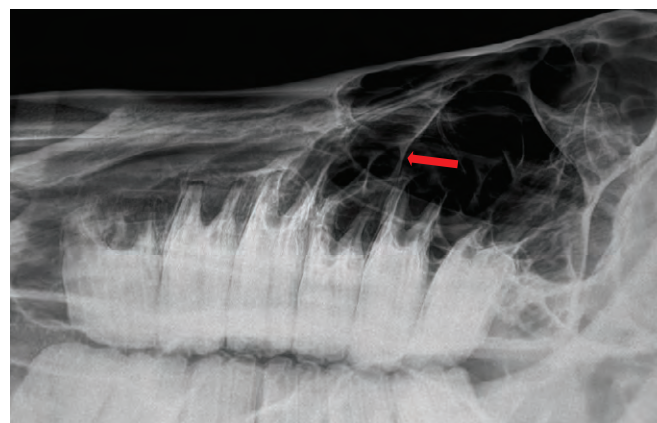


Fig. 13.30 Lateral oblique radiograph of the maxillary cheek teeth row of a 10-year-old horse. Note the pointed appearance of the apical areas which represents the development of 'true' roots. In this particular horse, the rostral root of the 08 is positioned rostral to the maxillary sinuses. Arrow = maxillary sinus septum.

The dental buds of the permanent cheek teeth in the young horse are large, rounded, radiolucent structures, with a striated, vertical radiodense pattern, which is due to partially calcified enamel folds (Fig. 13.26). As a dental bud develops into a cheek tooth, its apical aspect appears as a round, radiolucent area with a very wide periodontal space, which is termed an eruption cyst. The *lamina dura* is often not visible around the apices of developing teeth. The permanent equine CT erupt between 1 and 4 years of age (see Ch. 5). Between 2 and 4 years of age (Fig. 13.29), the reserve crown is very long, and many of the cheek teeth still have large eruption cysts. At this age, the ventral border of the mandible becomes convex in some breeds ('3- and 4-year-old bumps') to accommodate these large dental structures, and the ventral mandibular cortex beneath the eruption cysts is very thin or even appears fully eroded. This convex appearance is lost as the horse ages due to continued eruption of the reserve crown, maturation of the cheek teeth apices, and remodelling of the mandibular cortex.

As the horse ages and the cheek teeth erupt, the true roots (i.e., enamel-free areas) develop, and the apices change from being rounded to developing a number of pointed structures, i.e., true roots (Fig. 13.30). Bearing in mind that the equine cheek teeth erupt at different ages, it is normal for young horses to have adjacent cheek teeth with very

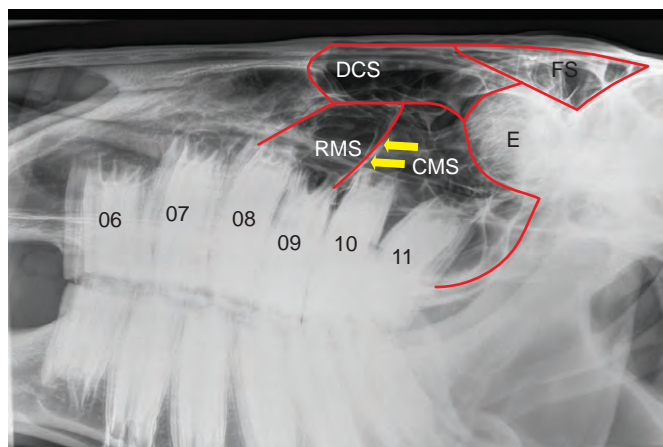


Fig. 13.31 Anatomy of the paranasal sinuses as viewed in a lateral radiograph. RMS, rostral maxillary sinus; CMS, caudal maxillary sinus; DCS, dorsal conchal sinus; FS, frontal sinus; E, ethmoturbinates; arrows, rostralateral portion of the maxillary sinus septum. The 06 and 07 are positioned rostral to the paranasal sinuses.

radiographically variable apical areas (Fig. 13.29). For example, major differences are present between the apices of the 08s (3rd cheek teeth) and 09s (4th cheek teeth) in a 4-year-old horse, because the 09 is 3 years older than the 08. Consequently, caution must be exercised when comparing the radiographic appearances of adjacent cheek teeth apices in young horses.

The apices of some equine maxillary cheek teeth are positioned within the paranasal sinuses, and knowledge of this anatomic relationship is important in order to detect changes due to periapical infections (Fig. 13.31). Although there is some individual variation, generally the apices and reserve crown of the 06s and 07s and rostral aspect of the 08s (Fig. 13.30) lie within the radio-opaque, rostral aspect of the maxillary bone, and therefore, a slightly higher exposure is required to image these optimally. The caudal aspect of the maxillary 08s and all of the 09s are generally positioned within the rostral maxillary sinus, and the maxillary 10s and 11s lie within the caudal maxillary sinus (Fig. 13.31).

The rostral and caudal maxillary sinuses are usually completely separated by a thin obliquely oriented bony septum which on lateral or lateral-oblique radiographs originates adjacent to the caudal aspect of the upper 09s, and courses from rostralateral to caudomedial. Although the maxillary sinus septum is not always radiographically distinguishable from other intrasinus septae, its most lateral aspect is often represented by a linear radiopacity,¹¹ extending dorsocaudally from the caudal aspect of the upper 09s (Fig. 13.31). The position of the maxillary sinus septae may vary between right and left sides. The infra-orbital canals are radiographically apparent on lateral and lateral-oblique radiographs, lying directly dorsal to the apices of the caudal cheek teeth in young horses.

Due to the different times of eruption, the reserve crowns of the permanent cheek teeth are not all the same length – the 09s are consistently shortest, these being the first permanent cheek teeth to erupt. The 06s are also shorter and squarer shaped than the other cheek teeth.

As the horse ages, the reserve crown of the cheek teeth reduces in length as the tooth wears at its occlusal aspect and



Fig. 13.32 Maxillary arcade of an aged horse (cadaver). The reserve crowns are very short, and the roots have lost definition due to excessive cementum deposition around their periphery ('hypercementosis'). A wave mouth is also present.

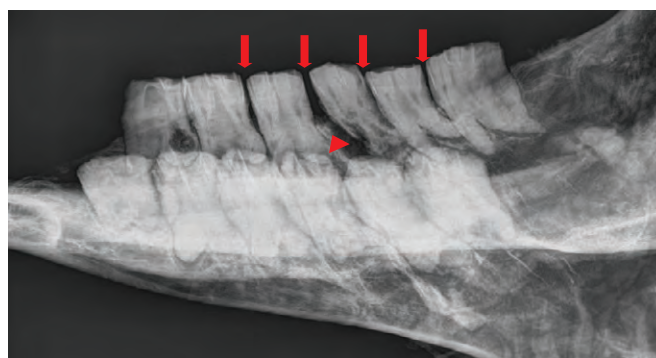


Fig. 13.33 Mandible of an aged horse (cadaver). The reserve crowns are very short, there is hypercementosis of the roots and multiple (senile) diastemata are present (arrows). The most severe diastemata have associated loss of bone from the alveolar crest (arrowhead).

continues to erupt, despite cementum being increasingly laid down around the roots (Figs 13.32 & 13.33). This apical hypercementosis has the effect of obscuring some radiographic detail of the tooth roots, and making them appear thicker (clubbed) and more radiodense. Equine cheek teeth taper in towards their roots, and as the reserve crown length shortens, the rostrocaudal length of the erupted crown therefore decreases. Because the cheek teeth are no longer tightly apposed on the occlusal surface, aged horses are predisposed to developing (senile) cheek teeth diastemata (Fig. 13.33) and periodontal infection, due to food pocketing in these spaces.

Radiological interpretation

Sensitivity and specificity of radiography

When using a diagnostic test in practice, it is useful to know the sensitivity and specificity of that test. The sensitivity of a test represents the probability that the diagnostic test will be positive, given that the disorder is present. Specificity represents the probability that the test will be negative, given that

the disorder is absent. Most studies published to date and outlined below have used film-based radiographic evaluation. It is likely that with the widespread use of digital and computed radiography in equine practice, our ability to radiographically detect dental abnormalities will be significantly improved.

Dental disorders

Radiographic changes consistent with periapical infection are most readily identified in the rostral maxillary equine cheek teeth whose apices lie rostral to the maxillary sinuses, and the mandibular cheek teeth, whose apices are contained within the mandible.⁹ In the more caudally positioned maxillary cheek teeth where secondary dental sinusitis is common, apical infections can be recognized with confidence in only 50–57 % of cases using radiography alone.^{9,12} Two more recent studies by Weller et al and Barakzai that have investigated the accuracy of radiography for diagnosis of equine dental disorders found radiographic sensitivities of 52 % and 69 % (respectively) and specificities of 95 % and 70%.^{13,14} The differences between the results of these two studies are likely to be attributable to the different anatomical distribution of disorders in the two studies, with a considerably higher proportion of cases with dental sinusitis in the latter study as compared to predominantly mandibular or rostral maxillary dental lesions in the study performed by Weller et al (2001).¹³ A further study, using computed radiography,¹⁰ reported that periapical sclerosis, periapical lucency, and clubbing of tooth roots are the most reliable radiographic changes associated with periapical infection, but that mild changes in any of these categories are not dependable indicators of infection. This study also reported that loss of the lamina dura denta is a very insensitive (high number of false positives), but highly specific (low number of false negatives) indicator of periapical infection.

Paranasal sinus disorders

The sensitivity (85.2 %) and specificity (79.2 %) of radiography for detecting abnormalities of the equine sinuses have been shown to be moderate.¹⁵ The findings of Barakzai et al's¹⁵ study are similar to the reported sensitivity (73–76 %) and specificity (79–80 %) of radiography for detecting acute sinusitis in human beings.^{16,17} It should be mentioned, however, that although radiography is a very useful tool for determining if sinusitis is present or not, establishing the cause of sinusitis can be considerably more difficult!

Abnormalities of development and eruption

Gross abnormalities of the erupted crown may be evaluated with a detailed oral examination; however, radiography is often useful in order to assess the structure of and location of the reserve crowns and apical areas.¹ Many radiographs of these disorders are presented in Chapter 8.

Brachygnathia (parrot mouth, Fig. 13.34), prognathia (sow mouth) and wry nose

Radiography is not usually required to diagnose these developmental disorders of the premaxilla and/or mandible;



Fig. 13.34 Intra-operative lateral radiograph. This foal has suffered a rostral mandibular fracture with resultant mandibular shortening. The premaxilla has been fitted with a bite plate to allow some contact with the remaining lower incisors and so help prevent further ventral deviation of the premaxilla. (Radiograph courtesy of P.M. Dixon.)

however, the radiographic appearance of the teeth associated with these abnormalities has been illustrated in a review of congenital dental disorders¹⁸ and in Chapter 19.

Oligodontia

The absence of a tooth or teeth due to failure of development of a tooth bud may result in abnormal occlusion and wear. This condition is common in miniature pony breeds (Fig. 13.35), and further images of this disorder are presented in Chapter 8.

Polydontia

Extra, or supernumerary, teeth may have a normal anatomy or may be misshapen, malformed, and often misplaced (see Ch. 8). Due to their abnormal apical areas, it may be difficult to definitively ascertain if supernumerary teeth are apically infected or not. Quinn et al¹⁹ described a 'domed soft-tissue opacity in the floor of the maxillary sinuses' dorsal to the apices of supernumerary 12s (Fig. 13.36) to be a relatively consistent finding in affected horses. Supernumerary teeth can easily go unrecognized, particularly if the entire cheek tooth row is not included in the radiograph. Supernumerary cheek teeth are often very long, due to lack of attritional wear, and diastemata may develop between supernumerary and adjacent teeth.

Dysplastic teeth

Teeth with abnormal structure are relatively common in equidae (Fig. 13.37), and it can be difficult to ascertain whether such teeth are apically infected or not. They may be associated with abnormalities of eruption and dental impactions, and also with periodontal disease.

Abnormalities of eruption

Disorders of eruption may affect the incisors (Fig. 13.38), canines, wolf teeth, or cheek teeth (Fig. 13.39) and are



Fig. 13.35 Oligodontia. The pony in (A) has anodontia of 308, 408 and 108, although the deciduous remnant ('cap') of one lower 08 is still present. Radiograph courtesy of P.M. Dixon. The pony in (B) has only 5 teeth in both mandibular rows, with large overgrowths of the upper 10s and 11s and secondary diastemata formation between the upper 09s and 10s.

often predisposed to by dental impactions, and malformed or malpositioned teeth. Radiography is invaluable in assessing which teeth are involved, which, if any, are deciduous, which are permanent, and which teeth to extract in order to treat the disorder.

Temporal teratoma (Fig. 13.40)

The clinical signs of temporal teratoma (anomalous dental tissue in the parietotemporal region of the skull) are often pathognomonic for this developmental disorder, but radiography can be very useful in order to confirm the diagnosis and evaluate the nature (whether or not it contains calcified dental structures), location, and size of the lesion prior to surgical excision.

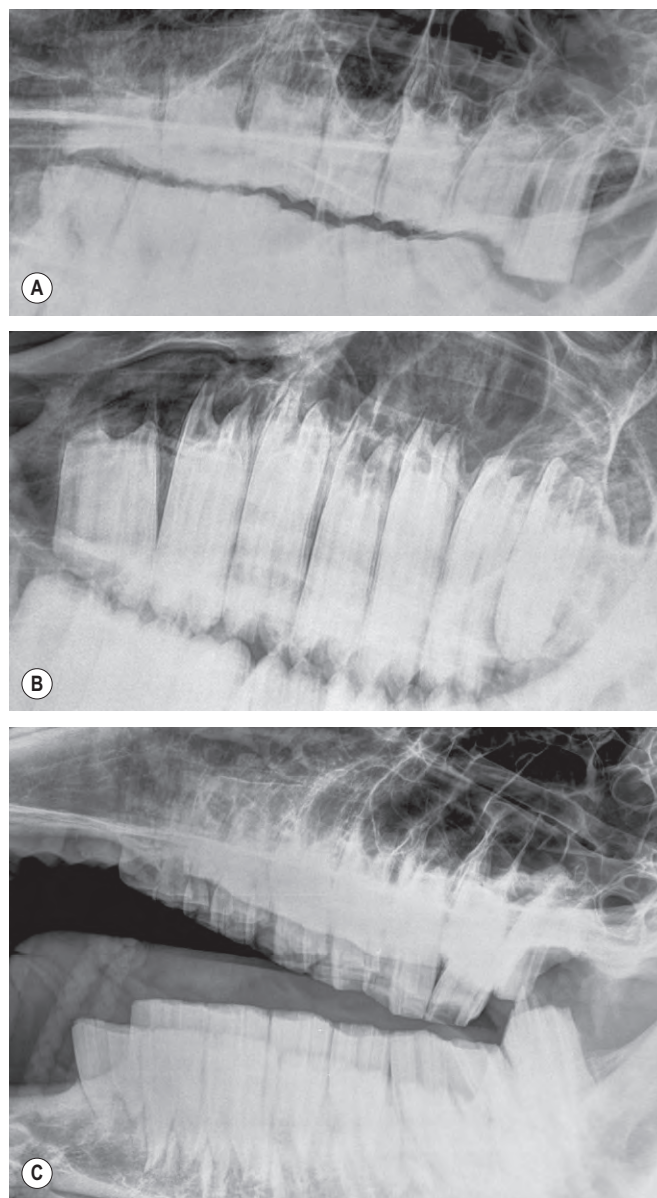


Fig. 13.36 Polydontia. Supernumerary maxillary cheek teeth (Triadan 12s) are the most common supernumerary cheek teeth in horses. The 12 is usually markedly overgrown as in (A) but may be unerupted as in (B) if there is inadequate space (overcrowding). Note the abnormal shape of the apical area of the 112. (C) An example of overgrown bilateral supernumerary mandibular 12s.

Apical infection (Fig. 13.41)

Both clinical and radiographic signs of periapical (apical) infection are often specific to the tooth involved. For example, the apices of the maxillary 06s and 07s (and variably the 08s) and all the mandibular cheek teeth are contained within thick bone; hence, cases of periapical infection of these teeth typically present with facial swelling, which appears radiographically as bone lucency often surrounded by sclerosis and periosteal new bone formation, and also cutaneous draining tracts. The maxillary 08s–11s apices are contained within the maxillary sinuses; hence, horses with periapical infection of these teeth present

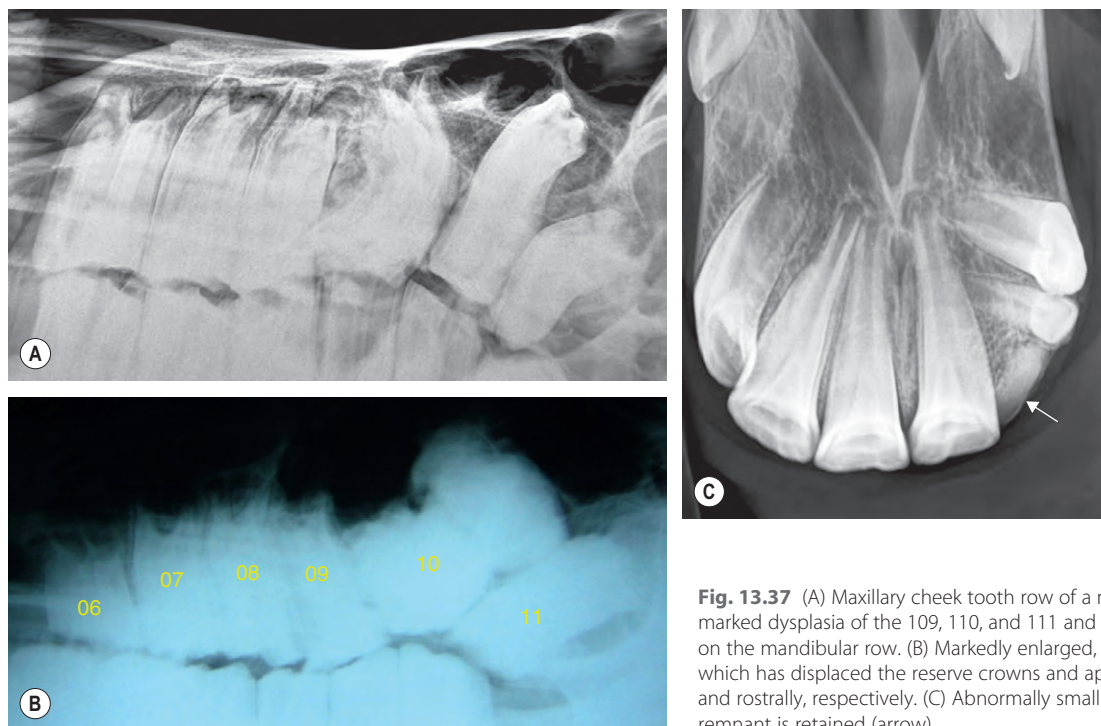


Fig. 13.37 (A) Maxillary cheek tooth row of a miniature Shetland pony with marked dysplasia of the 109, 110, and 111 and a corresponding wave mouth on the mandibular row. (B) Markedly enlarged, radiodense, dysplastic 110, which has displaced the reserve crowns and apices of 111 and 109 caudally and rostrally, respectively. (C) Abnormally small 302. The deciduous 702 remnant is retained (arrow).

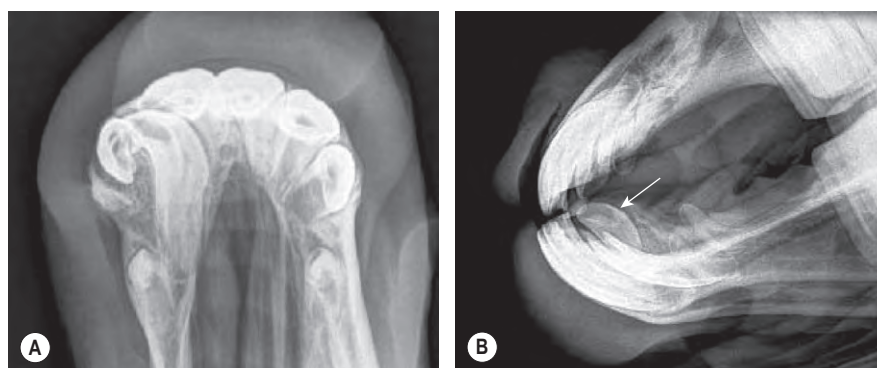


Fig. 13.38 (A & B) Malformed and malerupting 302 with retained deciduous 702. The malerupting 302 has an abnormal (reversed) rostral curvature in the lateral view (arrow) (B). 703 is present lateral to 702, but 303 does not appear to have developed. (Radiographs courtesy of B. Chilvers.)

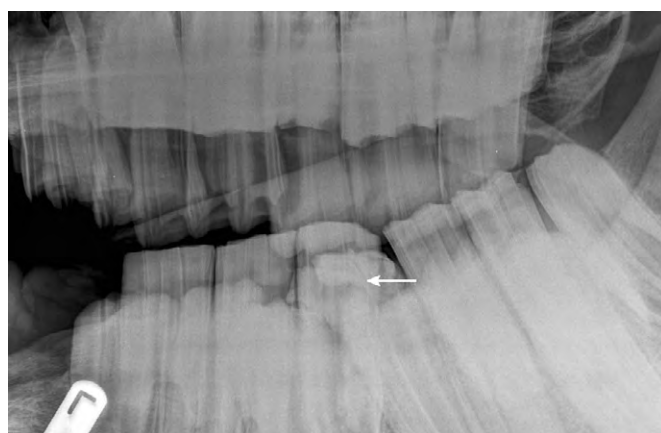


Fig. 13.39 This horse has retained 708 and 808 remnants which are displaced lateral and slightly caudal to the erupted permanent 08s (arrow).

clinically with nasal discharge and radiographically with changes associated with both dental infection *and* secondary sinusitis.

Radiographic changes consistent with early periapical infection include widening of the periodontal space and focal loss or irregularity of the *lamina dura*. When periapical infection has been present for many weeks, the affected apex and adjacent alveolar bone develop lytic changes, especially in mature teeth where the true roots (non-enamel areas) are well formed, due to decalcification and/or destruction of dental and adjacent alveolar tissues. These changes manifest as periapical radiolucent 'halos', and with time, a rounded or 'clubbed' appearance of the tooth roots can develop due to gross lysis/destruction of the root structures. In more chronic periapical infection, a zone of radiodense sclerosis may surround the periapical 'halo', due to new bone deposition around the lytic infected dental/alveolar area. More marked sclerosis develops around the apices of the rostral maxillary and mandibular cheek teeth than around the

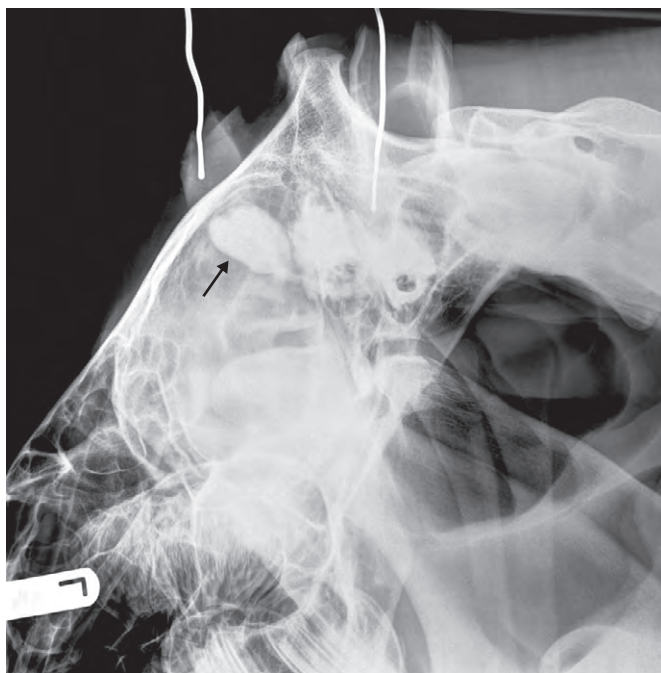


Fig. 13.40 Temporal teratoma. This horse presented with bilateral draining tracts just ventral to the pinnae that have had blunt metallic probes placed in them. One dentigerous cyst is seen as a rounded, tooth-like structure (arrow), positioned rostral to one of the tympanic bullae.

apices of the caudal maxillary cheek teeth, because the apices of the former teeth are positioned in denser bone than those of the caudal maxillary cheek teeth, which are situated in only thin alveolar bone within the maxillary sinuses.

External draining tracts are common with mandibular cheek teeth periapical infections and sometimes occur with rostral maxillary cheek teeth infections. These tracts may be apparent radiographically if there is a zone of bony sclerosis around their margins, but otherwise cannot be identified on plain radiographs. Infections of the caudal maxillary cheek teeth rarely present with external draining tracts, but affected horses may rarely have cellulitis of the masseter or pterygoideus muscles. If an external sinus tract is present, a blunt, malleable metallic probe should be inserted into the tract, and an appropriate lateral-oblique radiograph taken (Fig. 13.41D). This procedure can provide irrefutable evidence of dental disease, identify the affected apical area of the tooth, and provide a landmark for placement and angulation of the dental punch, if tooth repulsion is to be performed. Longer standing mandibular cheek teeth infections often have gross new mandibular bone formation beneath the affected apex, making the hemimandible thickened on palpation.

Focal, soft-tissue radio-opacities may also be apparent in the sinuses if periapical infection of the caudal 3–4 maxillary cheek teeth has occurred. These opacities may be due to a rounded, (soft tissue) granuloma or later, an encapsulated abscess developing over the infected apex. Fluid lines may be apparent in straight lateral views of the sinuses, due to accumulation of liquid purulent material. In cases of dental sinusitis, as in other sinusitis cases, inflamed and hypertrophied sinus mucosa may cause increased soft-tissue opacity within the sinuses.^{9,12}

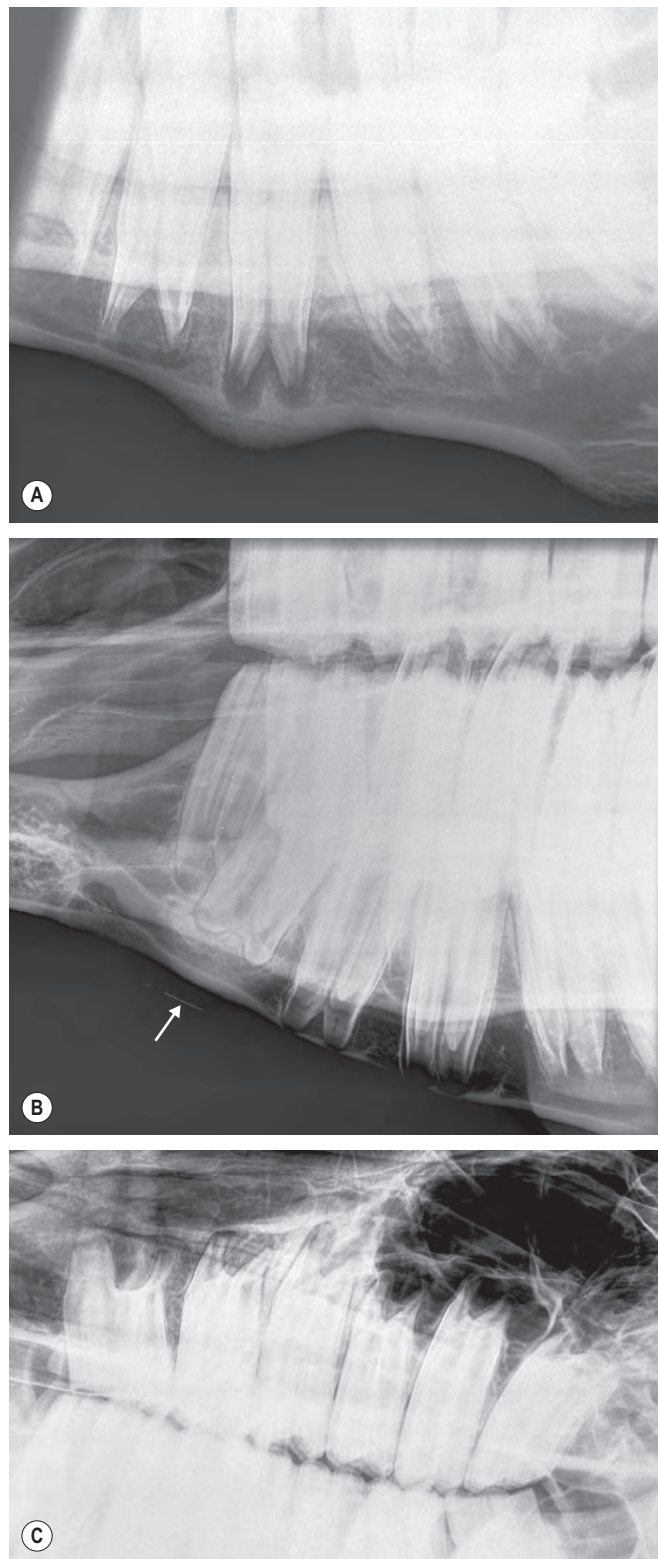


Fig. 13.41 Radiographic signs of periapical infection. (A) Radiolucent halos are evident around both roots of an infected 408, with widening of periodontal space, sclerosis of the ventral mandibular cortex and periosteal new bone deposition. (B) A zone of sclerosis is present around this infected 306. The affected apex is somewhat blunter than those of adjacent teeth; however, this can be a normal feature of 06s. An arrow points to a small radio-opaque marker placed on the skin at the site of facial swelling. (C) Infected 108. A periapical radiolucent halo surrounded by marked sclerosis is evident around the infected apex of this tooth, which lies outwith the rostral maxillary sinus in this horse.

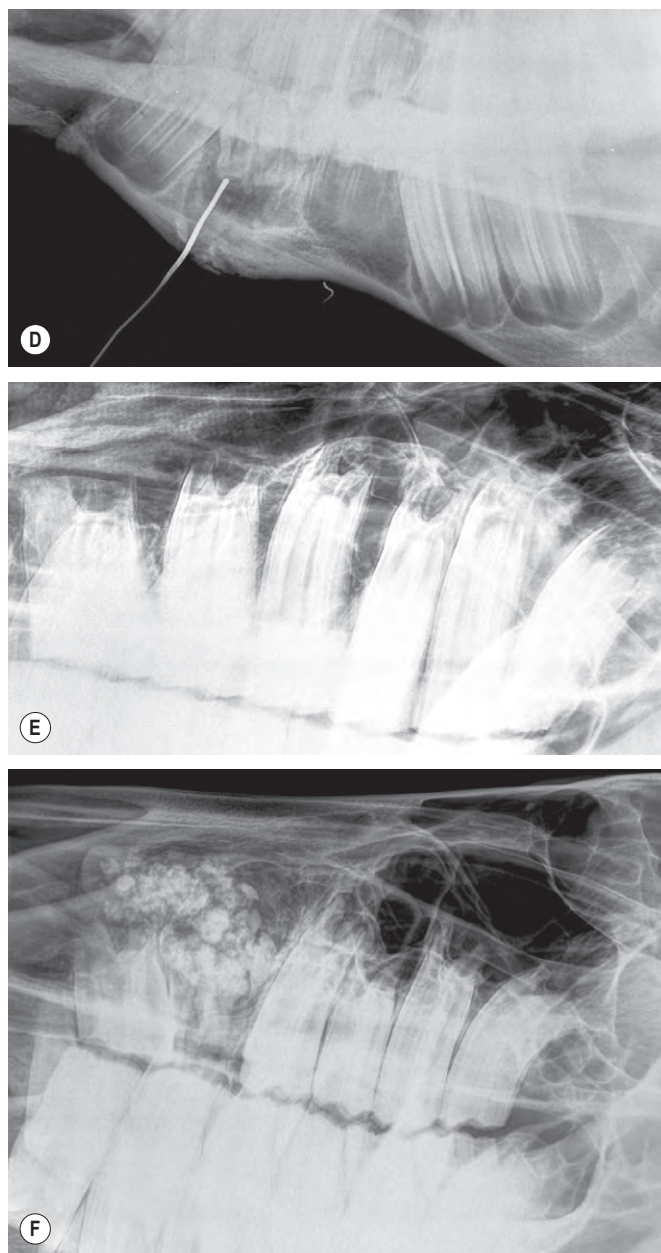


Fig. 13.41 continued (D) Gross destruction of the architecture of this infected 407 dental bud is present, with loss of much of the apical aspect of its crown. Multiple radio-opaque fragments are present in the alveolus, which may represent dental fragments or cementoma formation. A draining tract (with probe inserted) and gross mandibular new bone formation are evident. (E) Marked sclerosis is present around an apically infected 210. This horse had concurrent sinusitis. (F) Massive reactive cementoma deposition is present around the apex of chronically infected 207. Dystrophic calcification of the nasal conchae is likely also contributing to the radio-opaque appearance in the area rostral to the alveolus of 207. Most of the reserve crown of this tooth was still present; however, it is quite radiolucent, due to demineralization caused by chronic infection.

In less destructive chronic periapical infections, reactive abnormal deposition of (radio-opaque) cementum may occur on the infected tooth apex in an attempt to help control the infection, often resulting in an increase in size and blunting of the apex. In more destructive chronic



Fig. 13.42 Ameloblastoma of the rostral mandible, which has displaced the 303 laterally and caused erosion of the 302 and 301 incisors. These tumors can have varying degrees of calcification – this one is well calcified. (Radiograph courtesy of P.M. Dixon.)

periapical infections, no such repair process occurs and progressive destruction of the infected apex results in initial radiolucency and then loss of the apex and adjacent reserve crown of the affected tooth ('clubbing'). Dystrophic mineralization ('coral formation') of the cartilage of the nasal conchae may also occur with chronic maxillary cheek teeth periapical infections, particularly those involving the more rostrally positioned maxillary teeth.^{9,12}

Periodontal disease

Oral examination is superior to radiography for the detection and investigation of periodontal disease, but open-mouthed, oblique or intra-oral radiographs may occasionally be useful for demonstrating the effects of severe periodontal disease on the alveolar crest (Fig. 13.33) and adjacent structures. Occasionally, very severe and deep periodontal disease may extend towards the apex of the tooth and may be the cause of periapical infection. Radiography may be used to outline the dimensions of diastemata and the angulation and distance between the cheek teeth. It may also provide additional information on displaced teeth, which usually have associated periodontal disease.

Odontogenic tumors

Tumors of dental-tissue origin are all rare, but may be more common in horses than in other species²⁰ and are discussed in detail in Chapter 11. Five types of odontogenic tumors have been recorded in horses, and their radiological characteristics have been reviewed in detail.²¹ Ameloblastomas and ameloblastic odontomas can have a similar radiographic appearance.²¹ They are expansive, soft-tissue opacity masses containing lytic areas and sometimes areas of irregular granular calcification²¹ and often displace adjacent teeth (Fig. 13.42). Complex and compound odontomas are

irregular, tumor-like masses of dental tissues in well differentiated forms (Fig. 13.43). Complex odontomas contain all the elements of a normal tooth but within a disorganized structure, hence radiologically they appear as multiple, small, lobulated radio-opaque masses within a well-defined cyst-like structure.^{20,21} In contrast, compound odontomas contain an orderly pattern of dental tissues which form recognizable tooth-like structures. Cementomas are very radio-opaque mineralized structures, often rounded in appearance and associated with chronically infected tooth apices (Fig. 13.41F) or their alveoli following extraction of the infected tooth.

Other tumors and cystic structures affecting dentition

Any tumor or other space-occupying lesion affecting the mandible, incisive bone, maxilla, or paranasal sinuses may affect the teeth by displacing them or destroying their architecture, often through pressure resorption. Osteoma, osteosarcoma, osteoblastoma, chondrosarcoma, and fibrosarcoma are all tumors of bone that can arise in the regions of the equine jaws, and in the mandible in particular.²² It can be very difficult to differentiate between these individual tumor types radiographically, with proliferation of a bone-opacity mass being the most common radiologic presentation. Osteosarcomas may have a characteristic 'sun-burst' appearance of bone lysis and irregular, radiant deposition of reactive new trabecular bone. Other tumors of soft-tissue or mixed soft-tissue/bone origin, such as ossifying fibroma, fibrous dysplasia, and squamous cell carcinoma (Fig. 13.44) can have similar radiographic appearances to bony tumors as they often replace bone with fibro-osseous tissue. In their earlier stages, localized swellings caused by malignant tumors may be clinically similar to those caused by dental periapical infection, and consequently, the radiographic demonstration of bone destruction in the presence of normal dental apices may be an important differentiating feature of jaw tumors.¹ Cyst-like lesions of the mandible and paranasal sinuses of horses are commonly reported, and may displace the teeth due to their expansile effects.²³

Traumatic dental injuries

Horses with skull and in particular, mandibular fractures often have dental injuries, and radiography, along with detailed oral examination, is useful in evaluating such cases (Fig. 13.45). Fractures of the rostral mandible and premaxillary (incisive) bone occur frequently in young horses (Fig. 13.24A) and radiography may demonstrate whether temporary, permanent or both types of dentition have been damaged. Fractures of the cheek teeth also commonly occur alongside traumatic damage to the mid- and caudal mandible; however, even if identified acutely, treatment of dental fractures beyond removal of palpably loose fragments is usually best left until the supporting bone is healed as some fractured teeth can survive the acute pulpitis and do not become chronically infected.

Fractures of the erupted crown are more likely to be pathological (idiopathic cheek teeth fractures – see Ch. 10) or iatrogenic than traumatic in etiology, and these fractures are best imaged using an open-mouthed, oblique radiographic

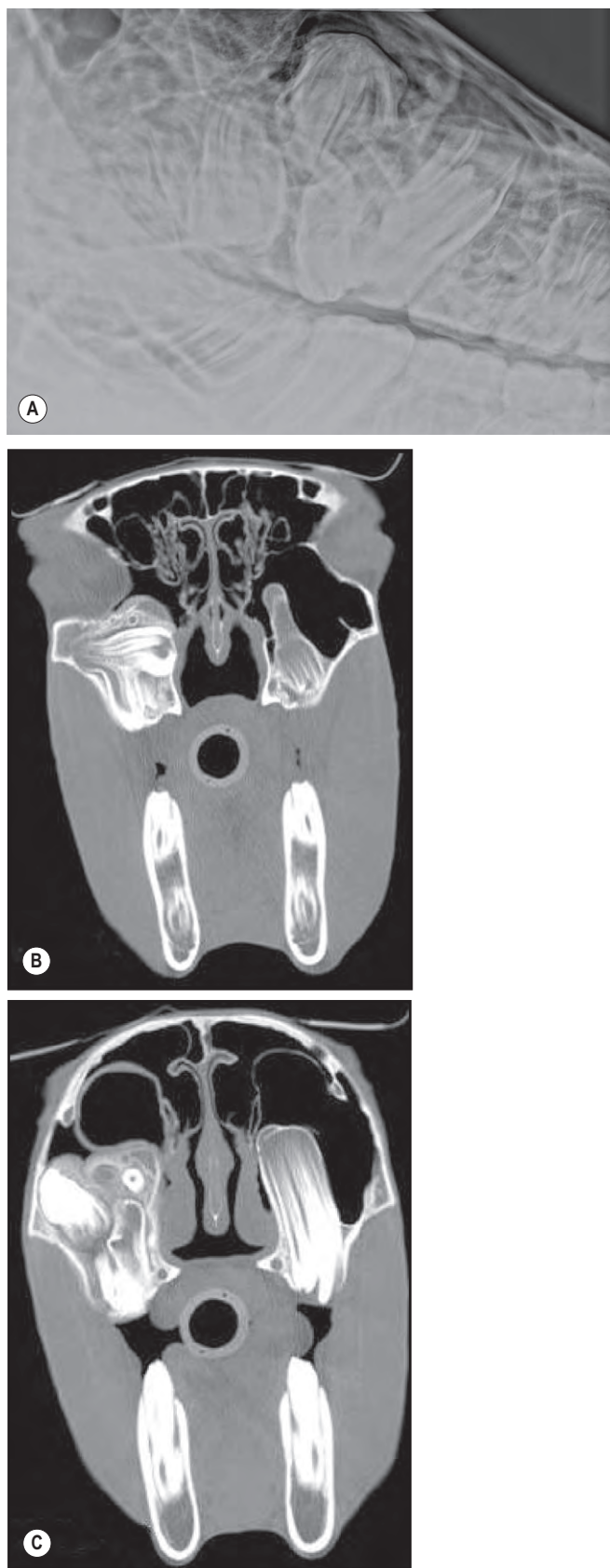


Fig. 13.43 Radiograph (A) and CT images (B and C) of a compound odontoma in a 2-year-old TB colt. (Images courtesy of J. Easley.)

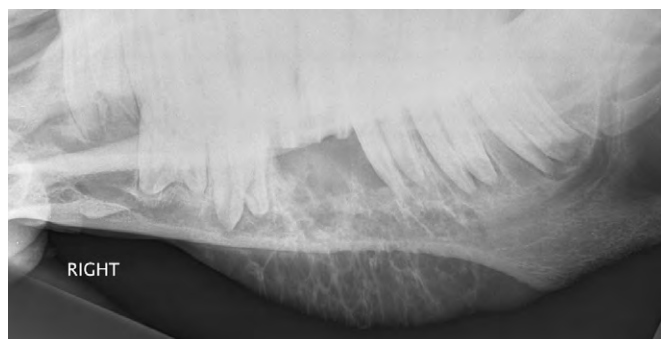


Fig. 13.44 Squamous cell carcinoma of the mandible with an unusual degree of linear calcification. Triadan 308 which was loosened by the invading mass has been extracted.

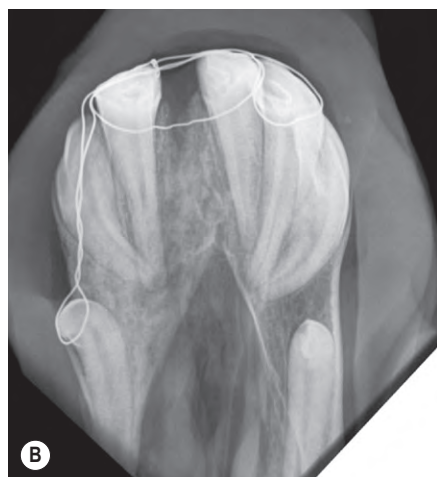
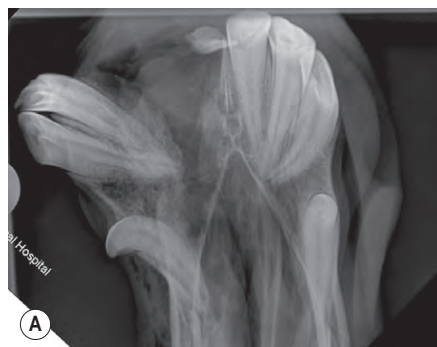


Fig. 13.45 (A) Pre- and (B) 6-week postoperative intra-oral radiographs of a horse with a complete, comminuted, displaced fracture of the pre-maxilla, with loss of one central incisor.

projection (Fig. 13.46). Imaging their apices is often also worthwhile.

Bitting injuries commonly involve the physiological diastema (interdental space; between the incisors and the cheek teeth), and radiographs may reveal sequestrum formation on the dorsal mandibular cortex and, rarely, a mandibular fracture (Fig. 13.47; see Chapter 9).

Scintigraphy

Scintigraphy is unique among the imaging modalities because the images reflect active physiological processes

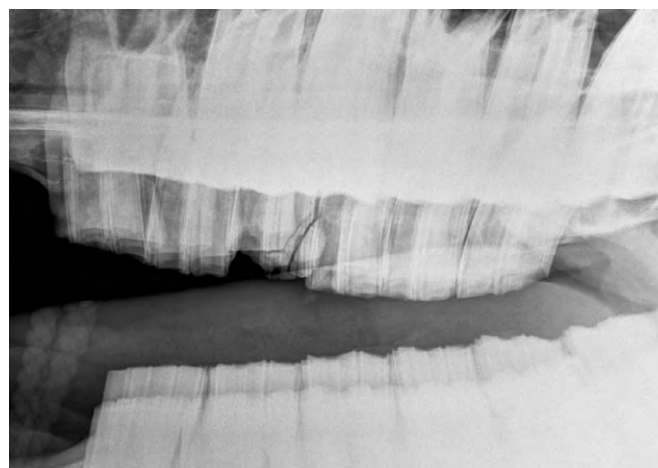


Fig. 13.46 Open-mouthed oblique radiograph of a horse with a fractured erupted crown of 108. A fragment is missing rostrally, and a displaced caudal fragment is still in place.

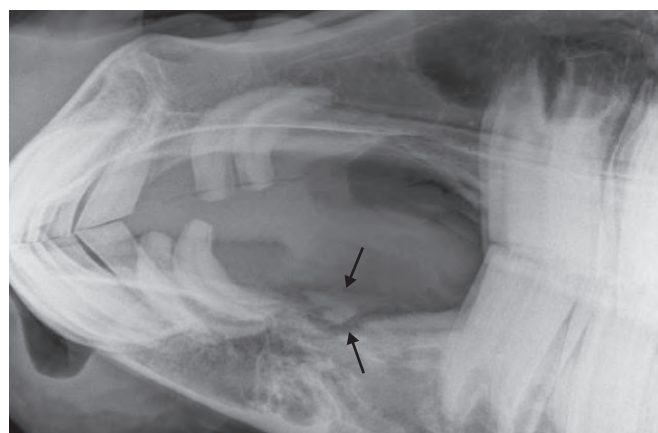


Fig. 13.47 This horse has a fracture of the interdental space – caused by damage from the bit when it stood on its reins. (Radiograph courtesy of P.M. Dixon.)

rather than the structural features portrayed by radiography, ultrasonography, CT, or MRI. Scintigraphy involves the intravenous administration of a gamma ray-emitting radioisotope, which is bound to a tissue-seeking molecule. ^{99m}Tc is currently the most commonly used radioisotope in the equine field, and is a meta-stable radionuclide that emits a gamma ray of 140 keV, with a physical half-life of 6 hours. The radio-isotope is cleared at a fast rate from the blood and soft tissues, and is incorporated selectively into bone in areas of resorption or formation.

Although scintigraphy has been used in equine orthopedics for many years, only recently have reports of its use for the detection of skull disorders in large numbers of horses begun to emerge.^{13–15,24,25} The ability of scintigraphy, using ^{99m}Tc bound to phosphates, to detect changes in bone before changes become radiographically apparent (because bone remodeling with increased bone mineral turnover usually precedes structural change) is one of the key advantages of this technique in the equine patient. Disadvantages of scintigraphy include the expense of setting up a dedicated

building, gamma camera, and appropriate software programs; licensing for the use, storage, and disposal of radioactive waste; appropriate stabling facilities that comply with radiation protection legislation; time required to isolate the patient (in most centers, horses are considered 'radioactive' for 24–48 hours post injection and cannot be handled), thereby delaying further diagnostic procedures or treatment; the requirement for technical expertise when reading scintigraphic images; and the risk of radiation exposure to personnel.

As noted, most equine skull scintigraphy is performed using the bone marker ^{99m}Tc -MDP. A dose of 1–1.5 GBq/100 kg bodyweight is administered intravenously, usually via a jugular catheter. Typically, only bone-phase images are acquired at 2–4 hours post injection, as the pool or soft tissue phase images do not usually provide any additional useful information, and collection of pool or soft tissue phase images considerably increases the radiation exposure of personnel.^{13,26} The use of ^{99m}Tc -hexa-methylpropyleneamine(HMPAO)-radiolabeled leukocytes has been described for equine dental scintigraphy,¹³ but it does not allow for positive identification of apical infections due to lack of anatomical resolution; additionally, its use incurs considerable additional cost compared to routine scintigraphy.

Heavy sedation is usually required in order to allow close positioning of the gamma camera to the patient and is achieved using a combination of an alpha-2 agonist (e.g., xylazine, detomidine, or romifidine) and butorphanol. A rope headcollar should be used to prevent artefactual 'cold spots' being recorded from buckles and rings on regular headcollars. The horse's head can be rested on a stool or similar object in order to minimize movement induced by sedation. Images may be acquired using static studies, which allows for their collection at a higher matrix size (256 × 256) which theoretically gives more detail; however, most horses will not remain adequately still during the required 1–2 minute acquisition period, and such movement causes distortion ('blurring') of both anatomical structures and lesions on static images. Dynamic studies (e.g., 30 consecutive 2 second frames, 128 × 128 matrix) are usually acquired in preference to static studies, because these may be 'motion corrected', which accounts for the inevitable movements of the horse's head during the acquisition period.

Scintigraphic views and normal anatomy

Right and left lateral, dorsal, and ventral views are the most commonly acquired equine skull scintigraphic views, with oblique views being occasionally useful for assisting lesion localization.²⁷ The reserve crowns of the cheek teeth appear as 'cold spots' of reduced uptake of radiopharmaceutical agent, and are surrounded by zones of increased radiopharmaceutical uptake (IRU) corresponding to the alveolar bone and interdental (interproximal) bone. The erupted crowns of the teeth are represented by an area of absent radionuclide uptake. The normal ethmoturbinates can be identified as a region of IRU positioned dorsally and caudally to the 6th maxillary cheek tooth and are located within the frontal sinuses. The normal temporomandibular joints are also focal areas of markedly IRU, as is the atlanto-occipital joint. The ventral and caudal cortices of the mandible and the zygomatic arch can be clearly identified as areas of high metabolic activity.

Periapical infection

Scintigraphy is most useful for diagnosis of cheek teeth periapical infection when used in combination with other diagnostic techniques, such as radiography and, of course, clinical examination.^{13–15}

^{99m}Tc -MDP uptake associated with periapical infection is typically focal and intense, with IRU located over the apical region of the affected tooth (Fig. 13.48). Region of interest (ROI) studies performed on cases of periapical infection have shown IRU of 24–259% greater than the same region on the contralateral side when using right and left lateral views.^{14,25} Because 'strike through' (lesions with high uptake may emit gamma rays from the contralateral side of the skull) may occur when comparing two lateral views, ROI taken from left and right sides on a dorsal (or ventral) view can show an even greater IRU% (as high as 700%¹⁴) on the affected side compared with the control side. If periapical infection is accompanied by secondary dental sinusitis, the focal intense uptake over the affected apex is surrounded by a diffuse region of moderately increased activity over the affected sinus(es) (Fig. 13.48B). After dental extraction, areas of IRU can be present for up to 24 months postoperatively (Fig. 13.49), presumably due to continued remodeling of the dental alveolus.¹⁴

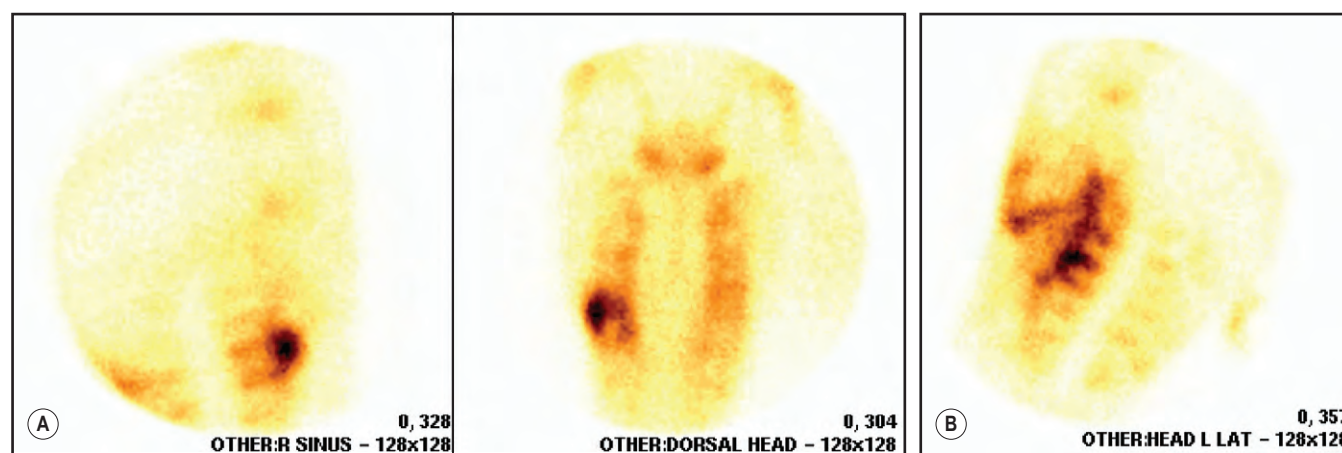


Fig. 13.48 Scintigrams of two horses with periapical infection of (A) 108 lateral and dorsoventral views and (B) 209 (this horse has concurrent sinusitis).

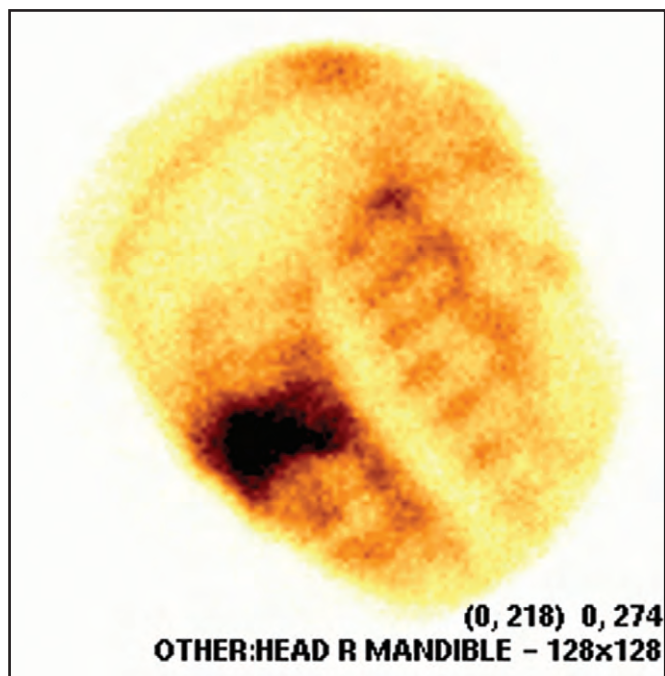


Fig. 13.49 Seven months after oral extraction of 409 the entire dental alveolus still exhibits marked uptake of radionuclide. This horse had no ongoing complications associated with the extraction.

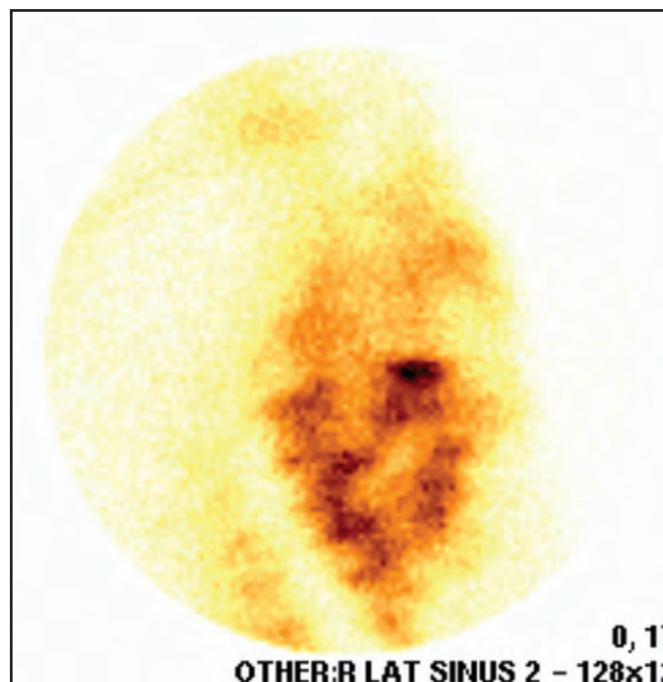


Fig. 13.50 Scintigram of a horse with primary sinusitis. Note there is a moderate uptake throughout the maxillary sinuses and a focal area of intense IRU within the sinuses, which is situated too far dorsally to be associated with the cheek teeth.

Differentiation of periapical infection from other skull lesions

Areas of IRU on scintigrams are not specific to any particular disease process; therefore, other disorders that cause remodeling or inflammation of osseous structures around the cheek teeth must be differentiated from cases of periapical infection.

Periodontal disease can cause areas of mild to moderate IRU on scintigraphy of the equine skull.^{13,14,25} However, because this disorder is often bilateral and multifocal and more commonly affects older horses where the cheek teeth are not clearly delineated, it can be difficult to definitively diagnose this disorder using scintigraphy. Periodontal disease should be clinically evident from a thorough examination of the oral cavity, and therefore there is little additional benefit from the use of scintigraphy in its diagnosis.

Horses with *primary sinusitis* may show variable patterns of IRU within the affected paranasal sinuses, but generally IRU is more diffuse and less marked (6–300%)^{14,25} than is seen with periapical infection. It should be possible to identify the rostral and caudal maxillary and frontal sinuses individually on scintigrams based on anatomical location with respect to the cheek teeth and ethmoturbinates.

Some cases of equine primary sinusitis exhibit focal area(s) of moderate to marked IRU (26–320% increase compared with contralateral side;¹⁴ Fig. 13.50). This is an important finding, because if these focal areas of IRU that are observed in cases of primary sinusitis happen to be positioned over the apex of a cheek tooth, a false diagnosis of periapical infection may be made. Careful, three-dimensional localization of the focal area of IRU may help prevent such false diagnoses in some cases.

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COMPUTED TOMOGRAPHY

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Introduction

Over the past decade, computed tomography (CT) has been increasingly used in equine examinations and is now available in many referral centers and university hospitals across the globe.^{28,29} CT is a valuable diagnostic tool³⁰ that provides detailed cross-sectional images of tissues, providing good bone and soft tissue contrast and eliminating the problem of tissue superimposition. CT examination of the equine head region is indicated in cases where clinical and radiographic examinations are inconclusive; when the exact location and extent of a lesion is needed for detailed therapy planning, such as for less invasive surgery or radiation or local chemotherapy,³¹ and also to accurately monitor cases following treatment.

CT has proven to be very useful in the diagnosis of fractures, dental disease, infection and neoplasia of the equine head. Protocols for the use of CT in evaluating the equine

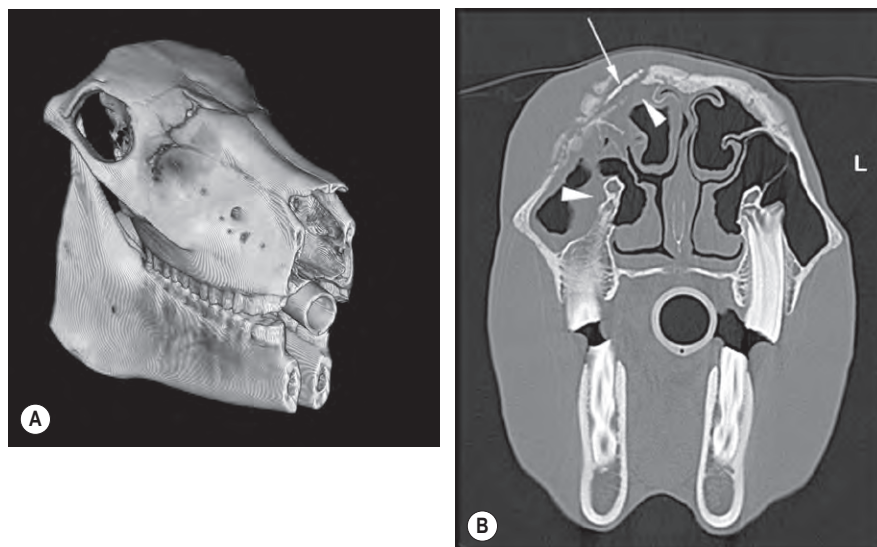


Fig. 13.51 Three-dimensional reconstruction (A) of the bone surface image of an irregular depressed fracture involving the right frontal, nasal, lacrimal, and maxillary bones in a 5-year-old Friesian gelding. The location of fracture lines largely coincides with anatomical suture lines. The distribution and extent of these fractures are well highlighted in the 3D-reformation.

Transverse section CT image (B) at the level of the caudal aspect of the upper 09s (1st molars) of the above horse. Marked subcutaneous soft tissue swelling is present, as is mild swelling of the mucosa of the right dorsal and caudal maxillary sinuses (arrowheads). Fragmentation of the right frontal and nasolacrimal bones is present with palisading new bone formations. A well-defined bone fragment, approximately 3 cm in length, which is hyperdense relative to the adjacent facial bones and separated from them by a 5-mm wide, hypodense rim can be clearly differentiated (arrow). The dorsal facial bones are bilateral irregularly thickened. These CT findings indicate sequestrum formation with surrounding osteomyelitis in an old fracture. The dental structures appear normal in these images.

head have been described in detail.²⁸ Despite the fact that CT is increasingly used for the diagnosis of equine dental disease, comparatively little information has been published to date on the appearance of equine dental tissues in health and disease.

Technical principles

CT is a cross-sectional imaging method that uses a rotating X-ray tube and detector system located in a gantry for image acquisition. When the narrow X-ray beam passes through a selected plane of the body, it is partially absorbed when it passes through tissues with different attenuation coefficients (density). Each tissue is assigned a value that represents its attenuation coefficient. Computerized reconstruction programs are used to assign a gray scale value that correlates to the attenuation value of the tissue being imaged.³² Different algorithms can be used for image reconstructions.³³ Each CT instrument manufacturer offers algorithms specifically designed for their individual hardware. For equine dental imaging, a soft tissue algorithm is useful for imaging of the soft tissue structures, followed by a reconstruction in a bone algorithm (high resolution) from the raw data, to allow detailed evaluation of dental and bony structures. The acquired sectional images can be reformatted in various two-dimensional planes or three-dimensional models (Fig. 13.51).

Evaluation of CT images for the presence or absence of dental disease is usually performed using a bone window.³⁴ By using this particular setting, the dental tissues (cement, enamel and dentin), as well as the lamina dura denta of the alveolus, can be differentiated according to their varying

radiodensities.³⁵ However, it is essential to also view the images in an appropriate soft tissue window setting for evaluation of possible changes in adjacent soft tissues. Objectively measuring the density of specific regions of interest (ROI) in Hounsfield Units (HU), allows for improved differentiation of soft tissues.^{32,36} Care must be taken not to perform measurements in areas that have inherent imaging artefacts, such as streaking artefact²⁸ (Fig. 13.52). In order to improve differentiation of soft tissue masses, post-contrast imaging following use of iodinated contrast agents can be acquired after local application of these agents into fistulous tracts or after intravenous injection.^{28,37}

General anesthesia is usually required for equine CT examinations, but more recently some clinics have acquired facilities to allow CT examination of sedated, standing horses to be performed.³⁸ CT examination of the anesthetized horse requires a custom-built table to allow precise positioning of the patient^{32,37} (Fig. 13.53). The horse should be positioned as symmetrically as possible³² in either lateral or dorsal recumbency, keeping the head (when in lateral recumbency) or the hard palate (when in dorsal recumbency) parallel to the table. The number, size and angle of slices can be planned after evaluating lateral (Fig. 13.54) and dorsal scout views. The gantry tilt should be minimized to reduce image distortion (especially for image reconstruction purposes). Contiguous, single- or multi-slice helical imaging protocols have been described,³⁵ the latter reducing scan time most. The recommended slice thickness ranges from 4 to 10 mm for evaluating the teeth and sinuses, and from 1 to 2 mm for evaluating special regions of interest (i.e., examining for specific changes in individual teeth or the temporomandibular joint). Two- and three-dimensional image reconstructions may assist in the diagnosis³⁹ and also

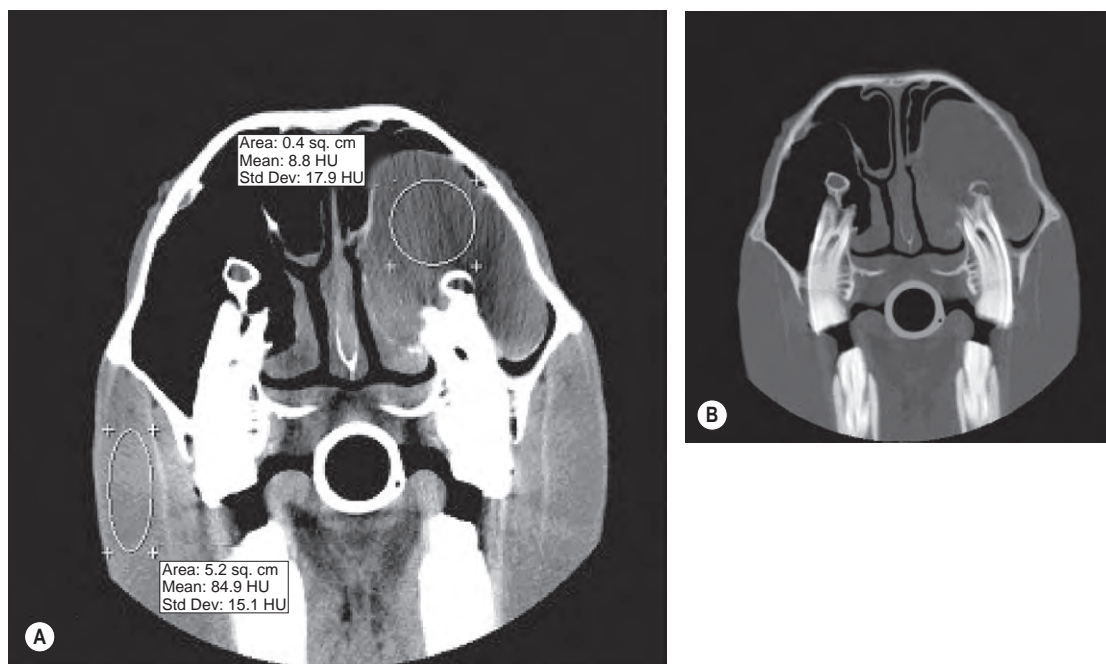


Fig. 13.52 Transverse images at the level of the caudal aspect of the Triadan 10s (2nd molars) of an 8-year-old Hannoverian mare in a soft tissue window (A) and bone window (B). A well-defined soft tissue mass lies within the left ventral conchal and caudal maxillary sinuses surrounded by a thin calcified wall and is causing compression of the dorsal conchal sinus. Density measurements within the mass revealed values of about 10 HU, which is indicative of fluid, whereas measurements of approximately 80 HU were present in the right masseter muscle, which is typical of soft tissue. Bilateral, mild, gaseous inclusions are present within the infundibula of both the maxillary cheek teeth that are imaged, but no significant abnormal dental findings were detected. These CT findings are suspicious of a sinus cyst that was later confirmed during surgery. There is gas present in both infundibula that must be differentiated from pulp disease, which would be much more likely to lead to sinus granuloma formation. Note the streaking artefacts dorsal to the left maxillary tooth within the lesion in the soft window settings (A) that are masked in the wide bone window settings (B). Artefacts compromise Hounsfield measurements.



Fig. 13.53 This horse under general anesthesia is positioned in dorsal recumbency on an air filled mattress with its head and legs fixed to the table. The head is positioned as symmetrically as possible.

improve surgical planning. The authors recommend the use of three-dimensional image reconstruction specifically in the evaluation of questionable periodontal or periapical disease.

Normal appearance of equine dental and periodontal tissues

On transverse CT images of normal teeth (**Fig. 13.55A**), the peripheral layer of cement is hypodense compared to adjacent enamel. The hyperdense zone of peripheral enamel

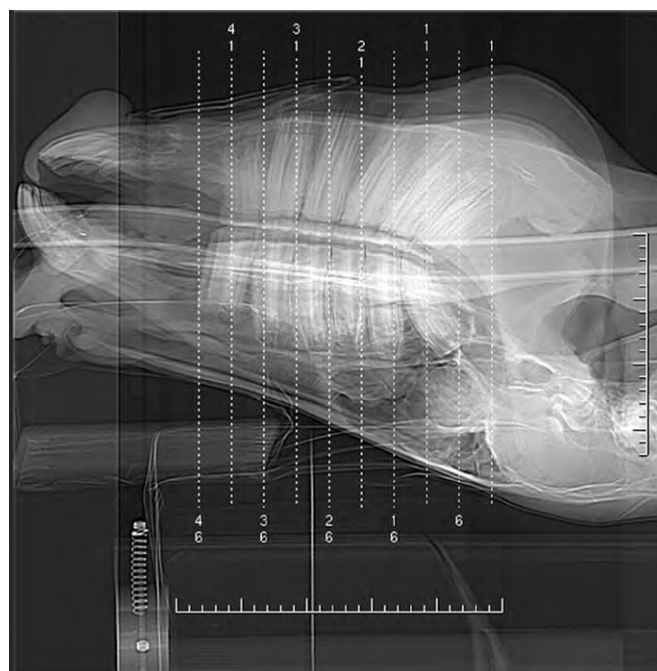


Fig. 13.54 Lateral scout view of a 4-year-old Pinto gelding under general anesthesia. The head is positioned with the hard palate almost parallel to the table so that transverse images are parallel to the long axis of uppermost (mandibular in this position) cheek teeth. The vertical dotted white lines resemble every 5th transverse slice.

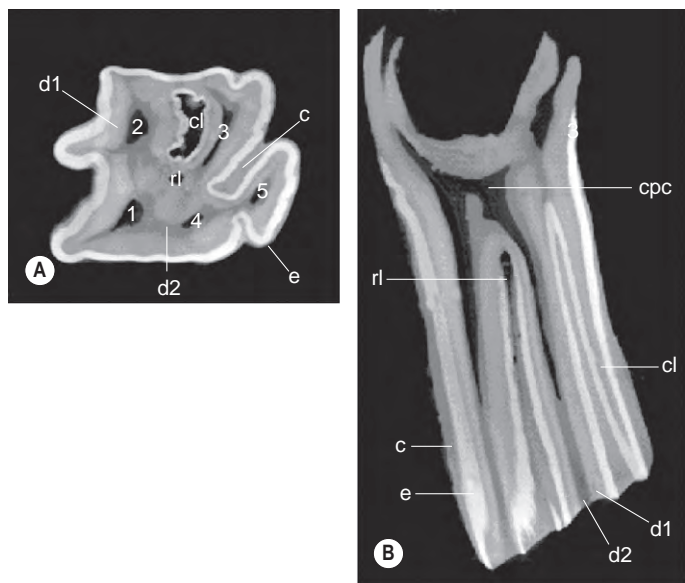


Fig. 13.55 Transverse (A) and sagittal (B) micro CT sections of an extracted Triadan 09 (1st maxillary molar). c, peripheral cement; e, enamel; d1, primary dentin; d2, secondary dentin; rl, rostral infundibulum. Hypodense gas inclusions where there is absence of infundibular cementum are indicative of infundibular cemental hypoplasia, cl, caudal infundibulum; 1–5, pulp cavities; cpc, common pulp chamber.

extends from the erupted (clinical) crown towards the apical region. Dentin is less radiodense than enamel and surrounds the hypodense pulp cavities.³⁵ The pathway of the pulp vasculature through the root canal(s) to the common pulp chamber (only present in recently erupted teeth) and the 5–7 individual pulp canals located in the reserve crown can clearly be followed over their length on 3-D reconstruction images of the cheek teeth. A column of dense secondary dentin lies over each pulp canal at the occlusal surface of normal teeth.

The rostral and the caudal infundibula are clearly seen in the maxillary cheek teeth, with each infundibulum surrounded by infolded enamel. In some teeth, a central infundibular vascular channel can be detected for the full length of the infundibulum on certain images. Although the central infundibular vascular channel canal is a hypodense structure in sagittal orientation, it must not be misinterpreted as a pulp cavity (Fig. 13.55B). In particular, infundibula may contain gas in cemental defects that must not be mistaken for an infected pulp.

The periodontal ligament appears as a narrow, linear, soft-tissue structure that separates the tooth from the surrounding alveolar bone. In healthy teeth, a thin layer of cortical bone, which is radiographically termed the lamina dura or dental lamina, lines the alveolus (Fig. 13.56). Several publications have described the normal CT anatomy of the equine head,^{28,33,40–43} including normal CT dental anatomy in detail,^{44,45} and more detailed information about normal CT findings can be found in these papers.

Pathological CT findings in equine dental disease

Signs of apical infection include: hypodense widening of the apical periodontal tissues (Fig. 13.57), sclerosis, and deformation or disintegration of the apical aspect of the lamina dura denta. Concurrent thickening of the overlying periapical soft tissue, sometimes containing gas inclusions, is also usually present. Granuloma formation appears as a soft



Fig. 13.56 Transverse CT section of a short 110 of a 16-year-old Warmblood gelding. The normal lamina dura (dental lamina) is outlined (arrowheads).

tissue mass around the apical area of the affected tooth (teeth), which is a feature of chronic dental disease (Fig. 13.58). Infection of the caudal four cheek teeth often leads to secondary sinusitis of the maxillary sinuses³⁴ (Fig. 13.59) when thickened respiratory epithelium, inspissated pus, and/or fluid-lines may be visible in the adjacent sinuses. As CT examinations are usually performed under general anesthesia in dorsal recumbency, purulent fluid originating from an infected cheek tooth may flow from the maxillary sinuses into the ipsilateral frontal sinus (Fig. 13.59).

Changes of the calcified dental tissues occur in long standing cases of apical tooth root infections. Deformation or fragmentation of tooth roots may be visible³⁴ (Fig. 13.59). In some chronic cases, considerable amounts of cement are deposited irregularly around the apex (as described in the gross pathology of these lesions in Chapter 10). Hypodense

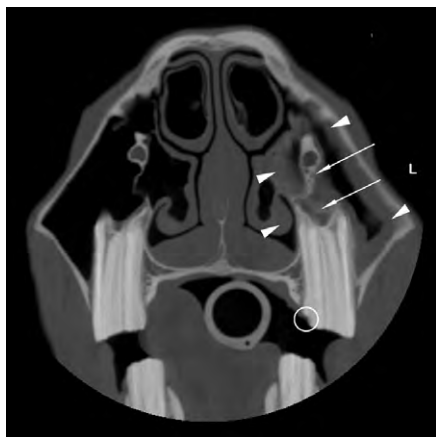


Fig. 13.57 Transverse CT section at the level of mid 209 of a 6-year-old Warmblood gelding that had an intermittent, purulent, left-sided nasal discharge. Moderate thickening is present in the rostral maxillary sinus mucosa and also medial to the infraorbital canal in the ventral conchal sinus (arrowheads). Mild to moderate widening of the periapical periodontal space is present, as is irregular thickening of the dental lamina (arrows) and of the bony plate lying beneath the infraorbital canal. A palatal slab fracture of 209 is present (circle) without any detectable overlying pulpar reaction.



Fig. 13.58 Transverse CT section at the mid-level of the maxillary 09s of a 5-year-old Quarter Horse. A focal soft tissue swelling (granuloma) surrounds the palatal root and hypodense 5th pulp cavity (arrow) of the 209. A fluid-line is present in the ventral conchal sinus (arrowhead) because the image was acquired in dorsal recumbency.

(black) areas indicating the presence of gas within the pulp or root canals are indicative of pulpitis (Figs 13.58 & 13.59), but many clinically normal equine maxillary cheek teeth have gas within areas of cemental defects in infundibula, that must not be mistaken as evidence of bacterial infection.

Whilst sagittal cheek teeth fractures are usually apparent on thorough clinical examination, they are difficult to diagnose radiographically. However, they are readily detected on CT images (Fig. 13.60) that also allow the configuration and extent of dental fractures to be fully evaluated. Transverse fractures of the teeth are relatively uncommon but may occur



Fig. 13.59 Transverse CT section at the level of the maxillary 110s of an 11-year-old Warmblood. Total opacification and mild expansion of the right caudal maxillary and ventral conchal sinuses are present. There is also some mucosal swelling in the ipsilateral dorsal conchal sinus. The apical dental lamina of 110 is widely separated from the apex and is sclerotic (arrowheads), and there is blunting of both visible roots and irregularity of the dental lamina on the buccal aspect of the affected tooth. A hypodense, bulbous enlargement is present in the proximal aspect of the 2nd pulp canal (arrow). A buccal slab fracture of the crown (circle) has caused changes in at least one (of the two) involved pulp horns.



Fig. 13.60 Transverse CT image of a 6-year-old Polo Pony at the mid 209 level. A sagittal midline fracture is present in 209, and the fracture site is packed with heterogeneous food particles. Note the irregularities and disruption of the apical dental lamina (arrow) and marked widening of the periodontal space. The rostral maxillary and ventral conchal sinuses are filled with food with gaseous inclusions. Some thickening of the overlying left nasal bone and mucosal swelling of the dorsal concha are also present.



Fig. 13.61 Transverse CT section at the level of the upper 09s in an 18-month-old Welsh Cob with facial swelling of suspected traumatic origin. The CT shows facial asymmetry, left-sided soft tissue (subcutaneous) swelling and thickening and irregularity of the external surface of the maxillary bone dorsal to the facial crest. The left dorsal and ventral conchal, and the rostral maxillary sinuses are completely filled with fluid and gas inclusions and, in turn, these structures are causing total obstruction of the left nasal passages and causing deviation of the nasal septum to the right side. An irregular, radiolucent line running transversely across the apical third of the reserve crown of 209 (arrowheads) and possibly some buccal axial deviation of this tooth are likely due to a traumatic fracture of this tooth. The irregular hypercementosis of the buccal peripheral cemental layer of this tooth and adjacent periodontal reactions are also likely of traumatic origin.

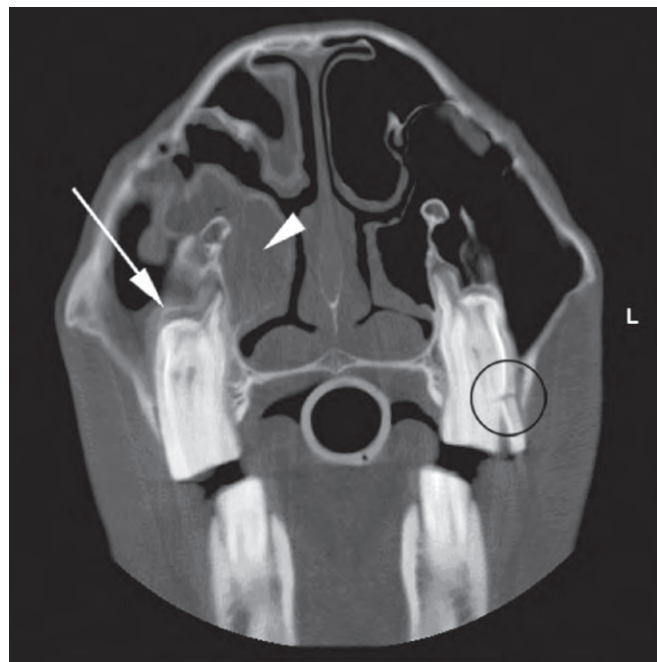


Fig. 13.62 Transverse section at the mid level of the Triadan 10s of an 8-year-old Noriker mare. A buccal slab fracture is present in 210 with exposure of the 1st pulp canal (these fractures also usually involve the 2nd pulp horn) but with no evidence of pulpar, apical, or periodontal changes currently apparent in this tooth. Note the rounded apical area of 110, adjacent periodontal widening (arrow) and complete filling of the right ventral conchal sinus (arrowhead) with fluid, indicative of apical infection of 110 with secondary sinus empyema.

secondary to trauma (Fig. 13.61). Lingual or buccal slab idiopathic cheek teeth fractures (Figs 13.62 & 13.63) have been described recently as the most common types of cheek teeth fractures in horses. In such fractured teeth, CT can usually distinguish between single and multiple pulp cavity involvement.⁴⁶ In some acute cases of dental fractures involving pulp cavities, pulpar changes are not detectable on CT (Fig. 13.62). These fractured teeth may be healing by production of tertiary dentin or, alternatively, might later develop clinical signs of pulpitis and subsequent periapical infection. In the latter type of case, magnetic resonance imaging is useful in the detection of periodontal disease, pulpitis and pulp necrosis.^{47,48}

Infundibular cemental hypoplasia and infundibular caries have been well described in equine teeth. Wide and air-filled irregular cavities can clearly be seen on transverse CT images of some clinically normal sagittally orientated infundibula³⁴ (Fig. 13.64). Although easily diagnosed using CT, infundibular changes are frequently present in horses that are asymptomatic and, in these cases, treatment such as dental extraction is not indicated. A diagnosis of severe infundibular caries penetrating the infundibular enamel is possible using CT examination, and such a finding is of great help



Fig. 13.63 Transverse CT section at the level of the upper 09s of a 4-year-old Thoroughbred mare. The 209 has a buccal slab fracture (with loss of fragment) affecting the 1st (or 2nd) pulp horn, which is slightly widened and hypoattenuated. The common pulp chamber of this tooth also contains a rounded, hyperdense structure 4 mm in diameter, most likely a pulp stone (arrow). The roots of this tooth (dental age 3 years) are blunt (rounded) and there is slight widening of the periodontal space apically and buccally. The buccal alveolar bone is heterogeneously thickened, and irregular sclerotic changes are also present in the periapical alveolar bone (arrowheads). The nasal conchae, including the left ventral and dorsal conchal sinuses, are irregularly thickened and distorted, and the adjacent ventral conchal and rostral maxillary sinuses are partially opacified due to the presence of exudate caused by the dental sinusitis.



Fig. 13.64 Transverse section CT image at the level of 207 in a 9-year-old Warmblood gelding. Gas is present in the proximal aspect of the imaged infundibulum with irregular thinning of the adjacent infundibular enamel (arrow). Penetration of caries through the infundibular enamel into the surrounding dentin may be present in this tooth.

when deciding whether to extract or preserve a maxillary cheek tooth. Dorsal plane reformatted images parallel to the occlusal surface show infundibular caries very well.

Considerable efforts have been made recently to improve diagnosis and treatment of periodontal disease. Detailed examination of the periodontal space on CT images can provide considerable information concerning the extent of periodontal disease. A specific equine periodontal disease classification system needs to be established in the near future. Periodontal changes that are detectable on CT range from mild, focal changes, such as widening of the (hypodense) periodontal space, cemental erosions, irregularities in the lamina dura denta (dental lamina), alveolar sclerosis or disruption, and extensive food and gas pocketing with destruction of the supporting maxillary or mandibular bones. The exclusion of periodontal disease is a prerequisite for endodontic therapy.

Dental-associated structures

Sinusitis is a common disease in equids and can be a primary sinusitis (i.e., caused by bacterial infection), or secondary to dental disease, trauma, cystic lesions, mycotic infections or neoplasia.^{32,34,49} One of the first changes of sinus disease detectable on CT imaging is a focal or diffuse swelling of the sinus mucosa, which must be differentiated from edema of the nasal conchae (turbinates) related to head positioning under general anesthesia.²⁸ A varying degree of intra-sinus fluid accumulation or increased density due to inspissated material and/or mucosal thickening can also be seen. In severe cases of sinusitis, the sinuses are entirely fluid-filled, and the sinus mucosa is indistinguishable from the surrounding fluid. In these cases evacuation of sinus exudate prior to CT examination may facilitate the examination. In



Fig. 13.65 Transverse CT section at the level of the 09s in a yearling. The occlusal surfaces of these unerupted teeth are still covered by soft tissue (dental sac). An expansive lesion above 209 has greatly disrupted the alveolus and adjacent structures. The enamel folds of 109 are irregular at their apical aspects, and the buccal surface of the peripheral enamel has a focal thickening (arrow). The inner borders of the periapical swelling have thick, irregular new bone formation (arrowheads), and the adjacent ventral conchal and rostral maxillary sinuses are completely filled with a hypodense substrate. The outline of the left facial crest is slightly irregular, and overall, the maxillary bone appears heterogeneous. In summary, these CT images indicate a chronic proliferative sinusitis and maxillary bone osteitis secondary to apical infection of the unerupted tooth.

long-standing cases, chronic distension of the sinuses with exudate can cause deviation of the nasal septum (Fig. 13.61), distortion of the nasal turbinates (conchae), the facial bones, and even dental apices. Chronic sinusitis may also cause thickening, endosteal sclerosis, and an irregular periosteal reaction of maxillary³⁴ and mandibular bone, and new bone formation may be present along the internal (Fig. 13.65) and external (Fig. 13.66) supporting bony walls of sinuses.

The presence of facial swelling and draining sinus tracts is a common reason for referral of equine patients. Dental disease, dentigerous cysts (heterotopic polyodontia; Fig. 13.67), head trauma, osteomyelitis and, infrequently, neoplasms of the head region are the most common causes of such facial swellings and tracts. In most affected horses, a definite diagnosis can be obtained using clinical and radiographic examinations. However, CT can be helpful in the examination of more difficult cases. Despite the fact that a specific tumor classification is not possible using CT, the extent and the grade of destruction of adjacent hard and soft tissues can be clearly evaluated, which enables a more accurate treatment plan and prognosis to be given (Fig. 13.68).

In complicated cases of ongoing dental-related disease, CT examination can be very helpful in assessment of treatments and, for example, in planning subsequent treatment strategies for oro-nasal fistulae (Fig. 13.69) or sequestration of



Fig. 13.66 Transverse CT section at the level of the upper 06s of a 2-year-old Quarterhorse. A normal eruption cyst overlies the 106 with the remnant of the underlying deciduous tooth (506) lying beneath it. A much larger, cyst-like swelling lies over the apex of 206 that is distorted and abnormally angled medially, towards the ventral nasal concha (arrow), with disruption of the medial aspect of the alveolus. A marked degree of smooth lamellar new-bone formation (arrowheads) has occurred along the adjacent maxillary bones along with adjacent subcutaneous soft-tissue swelling. These CT findings indicate chronic infection of the erupting 206 with penetration of exudate into the nasal cavity. Note the semicircular white line in the dorsal nasal passage due to injection of iodated contrast agent into the nasolacrimal duct that flowed to this site when the horse was in dorsal recumbency under general anesthesia during CT imaging.

alveolar bone or dental remnants, bone necrosis, or ongoing osteomyelitis (Fig. 13.51).

Disorders of the temporomandibular joints and hyoid bones can clinically mimic dental disease. The associated bony structures can be assessed accurately in CT. Alterations due to infectious disease and fractures have already been described.^{50–52} Typical features of infectious temporomandibular joint disease are widening of the joint space, bony defects, and soft tissue swelling (Fig. 13.70), as further described in Chapter 23.

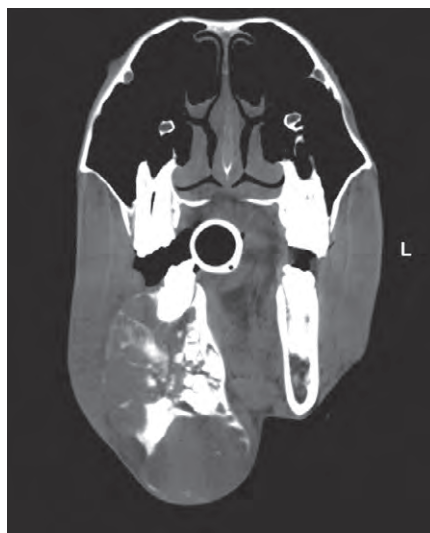


Fig. 13.68 Transverse CT image at the level of the 410 in a 12-year-old, New Forest Pony stallion, using a soft tissue window. Amorphous, hyperdense structures are clearly visible in the grossly enlarged and deformed right hemimandible. Such massive bony destruction caused by an expansile lesion is a feature of an ameloblastoma, which was diagnosed in this case. CT examination was invaluable for the planning of subsequent radiotherapy. The neoplasm did not enlarge for at least two years following this therapy.

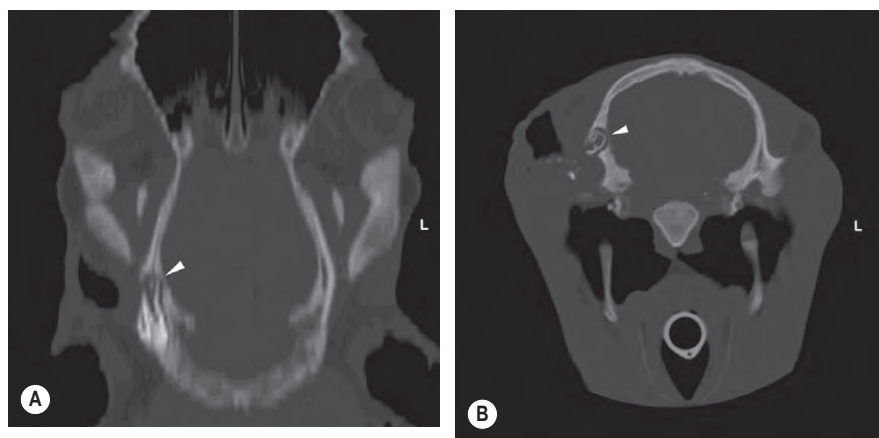


Fig. 13.67 Dorsal (A) and transverse (B) CT sections at the level of the temporal bone of a 6-month-old female Noriker foal. A horizontally orientated, heterotopic cheek tooth ('dentigerous cyst') lies within the right calvarium. The cerebral bony lamina is markedly thinned to just 1 mm wide (arrowheads) at the rostral aspect of this tooth. Gaseous inclusions and bony fragments lie within the soft tissues lateral and ventral to the dentigerous cyst, which was caused by the previous surgical removal of a second heterotopic tooth.

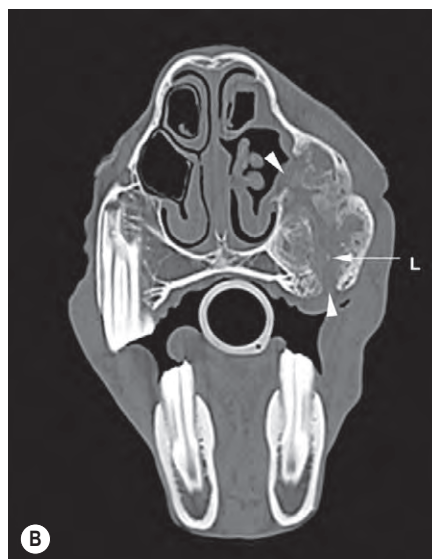


Fig. 13.69 Transverse CT images at the level of the 08s some 6 months following extraction of the 208, as viewed in a soft-tissue (A) and bony window (B). A soft-tissue swelling overlies the left maxillary bone, which has an irregular bulbous expansion and contains irregular, hypersclerotic areas. An oro-nasal fistula (arrowheads) is evident as an irregular lateral expansion of the maxillary bone, and a sclerotic appearance of the medial aspect of the ventral concha. An isolated, small, hyperdense bone sequestrum or dental remnant (arrow) is identified more easily in the soft tissue window (A) as compared to the bony window (B).



Fig. 13.70 Transverse CT images at the level of the temporomandibular joints (TMJ). Marked soft tissue swelling is present in the left temporal region. The left TMJ joint space is widened, and the joint has irregular bony surfaces. There are discrete, lytic changes in the subchondral bone of the mandibular condyle (arrows) and mild irregular periosteal new bone formation on the dorsolateral aspect of the left hemimandible (arrowhead). The articular disc can be identified as a slightly hyperdense structure lying in the center of the left TMJ.

References

- Gibbs C. Dental imaging. In: GJ Baker GJ, Easley J, eds. *Equine dentistry*, 2nd edn. Elsevier, Edinburgh, 2005, pp 171–202
- Baker GJ. Some aspects of equine dental radiology. *Equine Vet J* 1971; 3: 46–51
- Lane JG, Gibbs C, Meynick SE et al. Radiographic examination of the facial, nasal and paranasal sinus regions of the horse: I. Indications and procedures. *Equine Vet J* 1987; 19: 466–473
- O'Brien RT. Intra-oral dental radiography: experimental study in two horses and a llama. *Veterinary Radiology and Ultrasound* 1996; 37: 414–416
- Easley J. A new look at dental radiology. In: *Proceedings of the American Association of Equine Practitioners* 2002; 48: 412–420
- Barakzai SZ, Dixon PM. A study of open-mouthed oblique radiographic projections for evaluating lesions of the erupted (clinical) crown. *Equine Veterinary Education* 2003; 15: 143–148
- Klugh DO. Intraoral Radiography of Equine Premolars and Molars. In: *Proceedings 49th Annual Convention of the American Association of Equine Practitioners*, New Orleans, LA, USA. Ithaca: International Veterinary Information Service (www.ivis.org); Document No. P0640.1103, 2003
- Dixon PM, Copeland AN. The radiological appearance of mandibular cheek teeth in ponies of different ages. *Equine Veterinary Education* 1993; 5: 303–307
- Gibbs C, Lane JG. Radiographic investigation of the facial, nasal and paranasal sinus regions of the horse: II. Radiological findings. *Equine Vet J* 1987; 19: 474–492
- Townsend NB, Hawkes CS, Rex R, et al. Investigation of the sensitivity and specificity of specific radiological abnormalities for diagnosis of equine cheek tooth periapical infection. In: *Proceedings of the ECVS annual symposium*, Nantes, France, 2009 pp TO ADD
- Barakzai SZ, Knowles J, Kane-Smyth J, Townsend N. Trephination of the equine rostral maxillary sinus: efficacy and safety of two trephine sites. *Veterinary Surgery* 2008; 37: 278–282
- Tremaine WH, Dixon PM. A long term study of 277 cases of equine sinonasal disease. Part 1: Details of horses, historical, clinical and ancillary diagnostic findings. *Equine Vet J* 2001; 33: 274–282
- Weller R, Livesey L, Maierl J, et al. Comparison of radiography and scintigraphy in the diagnosis of dental disorders in the horse. *Equine Vet J* 2001; 33: 49–58
- Barakzai SZ. Use of scintigraphy for the diagnosis of suspected equine dental and paranasal sinus disorders. MSc Thesis, University of Edinburgh, 2005
- Barakzai S, Tremaine WH, Dixon P. Use of scintigraphy for diagnosis of equine paranasal sinus disorders. *Veterinary Surgery* 2006; 35: 94–101
- Engels EA, Terrin N, Barza M, Lau J. Meta-analysis of diagnostic tests for acute sinusitis. *J Clin Epidemiol* 2000; 53: 852–862
- Berger G, Steinberg DM, Popovtzer A, et al. Endoscopy versus radiography for the diagnosis of acute bacterial rhinosinusitis. *European Archives of Otorhinolaryngology* 2005; 262: 416–422
- DeBowes RM, Gaughn EM. Congenital dental disease of horses. *Veterinary Clinics of North America: Equine Practice* 1998; 14: 273–289
- Quinn GC, Tremaine WH, Lane JG. Supernumerary cheek teeth (n=24); clinical features, diagnosis, treatment and outcome in 15 horses. *Equine Vet J* 2005; 37: 505–509
- Knottenbelt DC, Kelly DF. Oral and dental tumors. In: Baker GJ, Easley J, eds.

- Equine dentistry, 2nd edn. Elsevier, Edinburgh, 2005, pp 127–148
21. Pirie RS, Dixon PM. Mandibular tumors in the horse: a review of the literature and seven case reports. *Equine Veterinary Education* 1997; 5: 287–294
 22. Cotchin E. A general survey of tumors of the horse. *Equine Vet J* 1977; 9: 16–21
 23. Lane JG, Longstaffe JA, Gibbs C. Equine paranasal sinus cysts: a report of fifteen cases. *Equine Vet J* 1987; 19: 537–544
 24. Archer DC, Blake CL, Singer ER, et al. The normal scintigraphic appearance of the equine head. *Equine Veterinary Education* 2003; 15: 243–249
 25. Archer DC, Blake CL, Singer ER, et al. Scintigraphic appearance of selected diseases of the equine head. *Equine Veterinary Education* 2003; 15: 305–313
 26. Gayle JM, Redding WR, Vacek JR, et al. Diagnosis and surgical treatment of periapical infection of the third mandibular molar in five horses. *Journal of the American Veterinary Medical Association* 1999; 215: 829–832
 27. Ramzan PHL. The head. In: Dyson SJ, Pilsworth RC, Twardock AR, Martinelli MJ, eds. *Equine scintigraphy*. *Equine Veterinary Journal*, Newmarket, Suffolk 2003, pp 225–226
 28. Solano M, Brawer RS. CT of the equine head: technical considerations, anatomical guide, and selected diseases. *Clinical techniques in equine practice* 2004; 3: 374–388
 29. O'Brien RT, Biller DS. Dental imaging. *Veterinary Clinics of North America: Equine Practice, Dentistry* 1998; 14: 259–271
 30. Heufelder B, Mettenleiter E, Tietje S, Traencker D-M. Fallbericht eines komplexen Odontoms beim Pferd – Klinik, Röntgen, Sonographie und Computertomographie. *Tierärztliche Praxis* 1994; 22: 155–158
 31. Annear MJ, Gemensky-Metzler AJ, Elce YA, Stone SG. Exophthalmus secondary to a sinonasal cyst in a horse. *Journal of American Veterinary Medical Association* 2008; 233: 285–288
 32. Tietje S, Becker M, Böckenhoff G. Computed tomographic evaluation of head diseases in the horse: 15 cases. *Equine Vet J* 1996; 28: 98–105
 33. Morrow KL, Park RD, Spurgeon TL, et al. Computed tomographic imaging of the equine head. *Veterinary Radiology and Ultrasound* 2000; 41: 491–497
 34. Henninger W, Frame EM, Willmann M, et al. CT features of alveolitis and sinusitis in horses. *Veterinary Radiology and Ultrasound* 2003; 44: 269–276
 35. Puchalski SM. Computed tomographic and ultrasonographic examination of equine dental structures: normal and abnormal findings. *Proceeding American Association of Equine Practitioners, Focus Meeting, Indianapolis, 2006*, pp 173–180
 36. Tietje S. Zur Bedeutung der Computertomographie beim Pferd, Teil 1: Erkrankungen an Kopf und Hals. *Der praktische Tierarzt* 1996; 77: 1090–1098
 37. Barbee DD, Allen JR, Gavin PR. Computed tomography in horses – technique. *Veterinary Radiology* 1987; 28: 144–151
 38. Nelson A. Computed tomography and joint disease. *Proceedings of the 47th BEVA Congress, Handbook of Presentations* 2008, p. 267
 39. Banner TA. Using computed tomography in evaluation of equine dental disease. *Proceeding American Association of Equine Practitioners, Focus Meeting, Indianapolis, 2006*, pp 289–292
 40. Smallwood JE, Wood BC, Taylor WE, Tate Jr LP. Anatomic reference for computed tomography of the head of the foal. *Veterinary Radiology and Ultrasound* 2002; 43: 99–117
 41. Probst A, Henninger W, Willmann M. Communications of normal nasal and paranasal cavities in computed tomography of horses. *Veterinary Radiology and Ultrasound* 2005; 46: 44–48
 42. Nöller C, Nowak M, Jamann J, et al. Klinische Anatomie der Nasen- und Nasennebenhöhlen des Pferdes – Grundlagen für die Endoskopie, Computertomographie und Chirurgie. *Tierärztliche Praxis* 2007; 23: 47–58
 43. Rodríguez MJ, Latorre R, López-Albors O, et al. Computed tomographic anatomy of the temporomandibular joint in the young horse. *Equine Vet J* 2008; 40: 566–571
 44. Windley Z, Weller R, Tremaine WH, Perkins JD. Two and three-dimensional computer tomographic anatomy of the enamel, infundibula and pulp of 126 equine cheek teeth. Part 1: Findings in normal teeth. *Equine Vet J* 2009; 41: 433–440
 45. Windley Z, Weller R, Tremaine WH, Perkins JD. Two and three-dimensional computer tomographic anatomy of the enamel, infundibula and pulp of 126 equine cheek teeth. Part 2: Findings in abnormal teeth. *Equine Vet J* 2009; 41: 441–447
 46. Bienert A, Bartmann CP. Kronenteilfrakturen im Bereich der Backenzähne des Pferdes. *Tierärztliche Praxis* 2008; 36(G): 266–272
 47. Gerlach K, Gerhards H. Erkrankungen von Pferde Zähnen in der magnetresonanztomographischen Diagnostik. *Vet-Med Report, Sonderausgabe V1/32. 20. Arbeitstagung der DVG-Fachgruppe Pferdekrankheiten*, 2
 48. Gerlach K, Gerhards H. Magnetresonanztomographische Merkmale von Zubildungen im Bereich der Nase, Nasennebenhöhlen und der angrenzenden Knochen: retrospektive Analyse von 33 Pferden. *Pferdeheilkunde* 2008; 24: 565–576
 49. Feige K, Geissbühler U, Fürst A, et al. Sinusitis beim Pferd: Eine retrospektive Untersuchung anhand von 55 Fällen. *Pferdeheilkunde* 2000; 16: 495–501
 50. Warmerdam EPL, Klein WR, van Herpen BPJM. Infectious temporomandibular joint disease in the horse: computed tomographic diagnosis and treatment of two cases. *Veterinary Record* 1997; 141: 172–174
 51. Chalmers HJ, Cheetham J, Dykes NL, Ducharme NG. Computed tomographic diagnosis – stylohyoid fracture with pharyngeal abscess in a horse without temporohyoid disease. *Veterinary Radiology and Ultrasound* 2006; 47: 165–167
 52. Nagy AD, Simhofer H. Mandibular condylectomy and meniscectomy for the treatment of septic temporomandibular joint arthritis in a horse. *Veterinary Surgery* 2006; 35: 663–668

Ancillary diagnostic techniques

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Cytological examination and culture of exudate

Empyema of the paranasal sinuses is a common complication of periapical infection of those cheek teeth whose apices reside within a maxillary sinus and of primary infection of the upper portion of the respiratory tract. Determining the underlying cause of paranasal sinus empyema is important because the cause of empyema influences treatment of the affected horse. Although periapical infection of teeth rostral to the maxillary sinuses is readily identified during radiographic examination of the skull, periapical infection of teeth within the sinuses can be confidently recognized in only about half of affected horses.¹

To help determine whether empyema is caused by dental disease or by primary infection, exudate obtained by centesis of the paranasal sinuses can be examined cytologically and cultured for bacteria. Exudate from within the paranasal sinuses can be obtained by introducing a dog urinary catheter through a small portal created in the frontal bone at a site one-third of the distance from the medial canthus of the eye to the dorsal midline, and 0.5 cm caudal to a line connecting the medial canthi.² The portal can be created by making a stab incision in the skin and either drilling through the frontal bone with a small, trocar-tipped, Steinmann pin using a Jacob's chuck or by driving a steel, 14- or 16-gauge, hypodermic needle through the frontal bone with a mallet. The needle should be removed before introducing a catheter into the sinuses. The catheter is passed through the portal and advanced through the underlying frontomaxillary aperture until it contacts the floor of the caudal maxillary sinus where exudate, if present, can usually be found, regardless of the site of disease causing empyema. If no exudate can be obtained, 10–20 ml of sterile, isotonic saline solution should be instilled into the sinus and aspirated (Fig. 14.1).

Identifying a single bacterial species during cytological examination of the exudate or culturing a single bacterial species from the exudate indicates that the empyema is probably caused by primary bacterial infection.³ If empyema is caused by periapical dental infection or an orosinus fistula, multiple types of bacterial colonies are identified, and plant material can sometimes be seen in the exudate.

A wide variety of bacteria, including aerobic and anaerobic, Gram-positive and Gram-negative bacteria, have been isolated from exudate obtained from the sinuses of horses affected with primary bacterial sinusitis. Hemolytic *Streptococcus* spp. are the most commonly isolated bacterial species.^{4,5} *Streptococcus equi* var. *equi*, the cause of strangles, is rarely isolated,^{3,6,7} but the presence of this organism may be masked by the overgrowth of other bacterial species. If a horse suffering from sinusitis has had signs typical of strangles, PCR examination of exudate obtained from the paranasal sinus should be considered to rule out infection caused by *S. equi* var. *equi*.⁸ The clinical significance of isolating bacterial species other than hemolytic *Streptococcus* spp. is largely unknown. Culture of exudate from the paranasal sinuses of horses affected by primary bacterial sinusitis can yield multiple bacterial isolates, especially if the infection is long-standing or if the horse has received prolonged administration of one or more antimicrobial drugs,⁴ and therefore, definitively determining the organism responsible for primary infection of the paranasal sinuses on the basis of microbial culture of the exudate is difficult. Waiting for results of bacteriological examination before proceeding with other diagnostic tests, such as sinoscopic or radiographic examination of the sinuses, may not be warranted.

Odor is seldom helpful in determining the cause of paranasal sinus empyema. Although nasal discharge produced because of primary sinusitis is usually not characterized by necrotic odor,⁹ primary bacterial sinus empyema can result in a necrotic odor to the horse's breath⁷ if the exudate becomes inspissated, because expansion of the inspissated exudate causes necrosis of surrounding tissue. Relying on odor to distinguish primary sinusitis from sinusitis occurring secondary to other disease, such as dental infection, may result in inaccurate diagnosis.

The ventral conchal sinus is frequently the compartment of the paranasal sinuses in which exudate becomes inspissated,⁴ and a large volume of inspissated exudate within this compartment usually signifies that the empyema is caused by primary infection (authors' observation).

Empyema of the paranasal sinuses caused by periapical dental disease (i.e., dental sinusitis) is frequently associated with a necrotic odor because periapical dental infection is



Fig. 14.1 A sample of exudate is obtained from the sinuses for bacteriological examination using a dog urinary catheter.

usually accompanied by anaerobic infection of alveolar bone.¹⁰ Mycotic infection of the paranasal sinuses should also be considered if paranasal sinusitis is accompanied by a malodorous nasal discharge.¹¹ A space-occupying lesion, such as a neoplasm or a progressive ethmoidal hematoma, may also produce a malodorous nasal charge from destruction of surrounding tissue or stagnation of mucosal secretions.

Percussion

Percussion of the paranasal sinuses is performed by rapping one's knuckles against the facial bones overlying the sinuses and listening for a difference in resonance between right and left sinuses. Percussion may identify loss of resonance within the sinuses, especially if sinuses are completely filled with fluid or tissue, but percussion, in general, is unreliable for detecting disease within the sinuses.¹² Resentment of the horse to percussion, however, may signify the presence of inflammation within the sinuses. Percussion is best performed with the horse's mouth held open with a speculum so that sound produced by percussion is not dampened by being transferred through the mandible.

Rhinoscopy

Rhinoscopy is performed with a flexible, video- or fiberoptic endoscope, with the horse standing. Rhinoscopy is indicated to determine the source of purulent exudate discharging from an external naris. The source of purulent exudate at an external naris could be the ipsilateral nasal cavity or paranasal sinuses, a guttural pouch, the nasopharynx, or the lungs. Finding exudate consistently at only one naris implicates the ipsilateral paranasal sinuses or nasal cavity as the source of

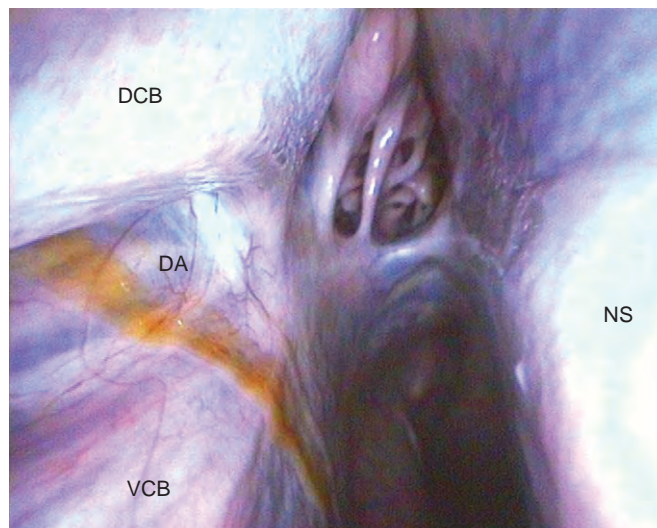


Fig. 14.2 Rhinoscopic image of the right caudal middle meatus showing exudate exiting the 'drainage angle' of the right paranasal sinuses. DCB, dorsal conchal bone; VCB, ventral conchal bone; DA, drainage angle; NS, nasal septum.

the exudate. Exudate that originates within the paranasal sinuses can usually be observed, during rhinoscopy, discharging into the middle nasal meatus at the drainage angle located at the caudal aspect of the nasal cavity (Fig. 14.2).

Rhinoscopy is also indicated to determine the cause of obstruction of the nasal cavity. Obstruction, even mild obstruction, can often be detected by placing the palms of the hands in front of the nares and comparing the volume of air exhaled from each nasal cavity.¹² A nasal cavity can become obstructed from a mass originating within the nasal cavity, such as a progressive ethmoid hematoma expanding from the nasal portion of the ethmoid labyrinth, or from axial deviation of the conchae caused by an expanding mass within the paranasal sinuses, such as a neoplasm, an osteoma, a cyst, inspissated exudate, or a progressive ethmoidal hematoma whose origin is the sinusual portion of the ethmoidal labyrinth (Fig. 14.3). Partial or complete obstruction of the nasomaxillary aperture may also result in axial deviation of the conchae from accumulation of exudate. A horse that has developed distortion of the facial bones rostral to the eye should be examined endoscopically to determine if the nasal conchae have also been distorted. Axial distortion of the nasal conchae indicates that the facial distortion is caused by an expanding mass or large volume of exudate within the paranasal sinuses. Sometimes, subtle deviation of the conchae can be appreciated only by endoscopically comparing the circumference and morphology of the two nasal cavities. Distortion of the conchae is not commonly caused by dental disease.

Lesions encountered during rhinoscopy associated with dental disease include oronasal or oromaxillary fistulas (Fig. 14.4), apical granulomas, and displaced teeth. An apical granuloma is visible during rhinoscopy within the rostrilateral aspect of the nasal cavity and is caused by periapical infection of the 2nd, 3rd, or 4th premolars (Triadan 06–08). If accompanied by an oro-nasal fistula, the granuloma is sometimes covered with exudate and feed. Removal of the feed reveals the granuloma (Fig. 14.5).

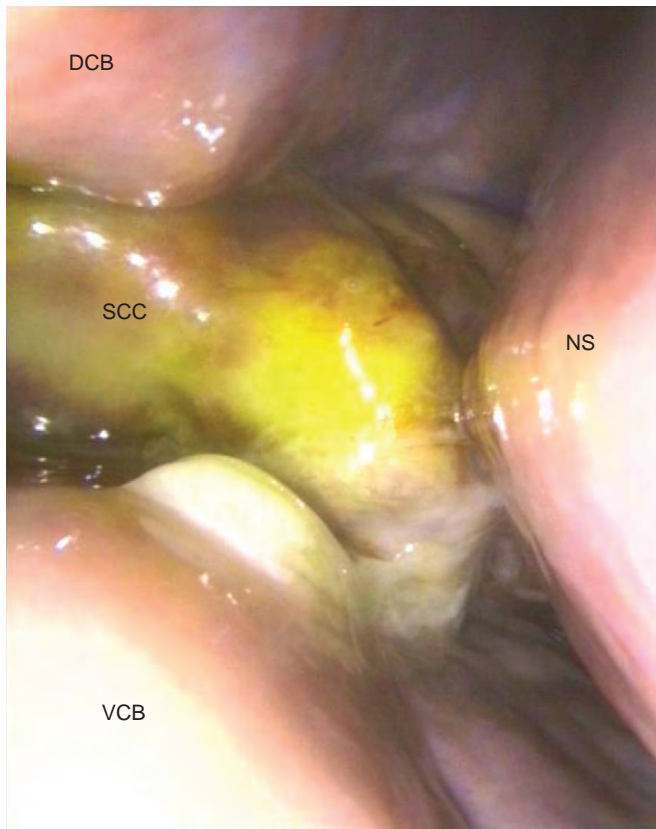


Fig. 14.3 Rhinoscopic image of the left middle meatus of a horse with a squamous cell carcinoma growing through the nasomaxillary aperture obscuring the drainage angle and middle meatus. DCB, dorsal conchal bone; VCB, ventral conchal bone; NS, nasal septum; SCC, squamous cell carcinoma.

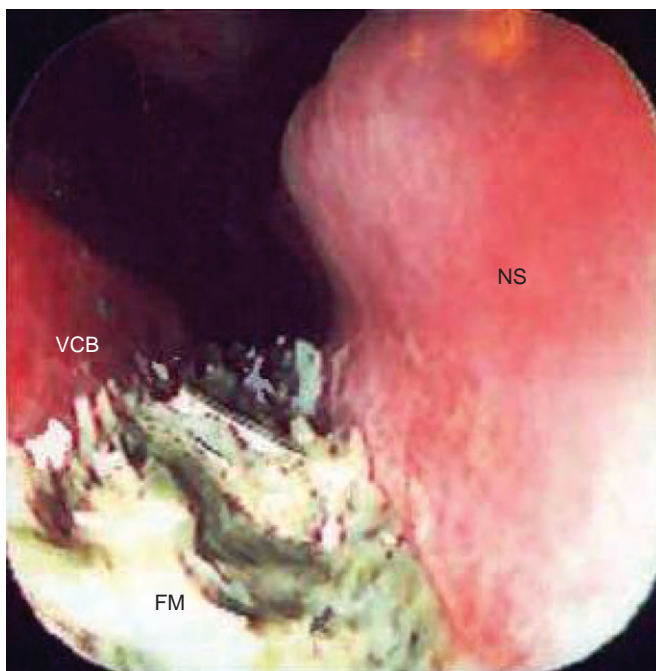


Fig. 14.4 Rhinoscopic image of the right nasal cavity showing accumulation of food in the ventral meatus. VCB, ventral conchal bone; NS, nasal septum; FM, food material.

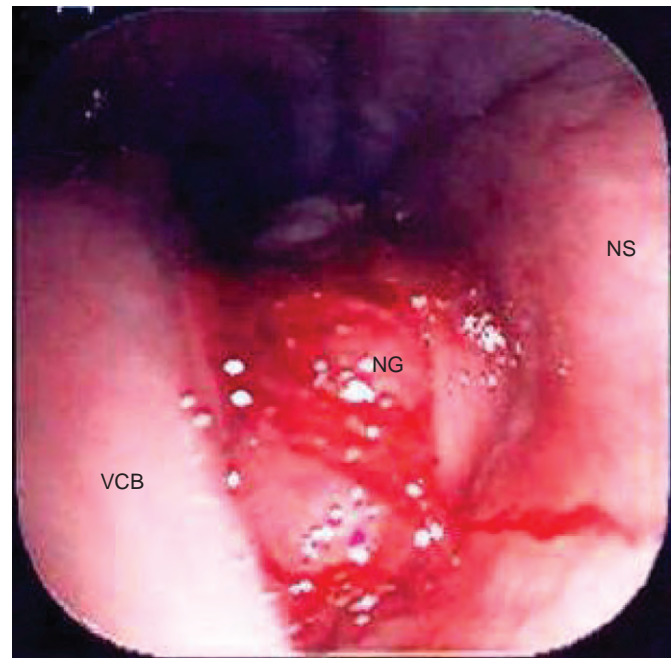


Fig. 14.5 Rhinoscopic image of the right nasal cavity showing a granuloma associated with an oro-nasal fistula in the ventral meatus. VCB, ventral conchal bone; NS, nasal septum; NG, nasal granuloma.

Sinoscopy

The primary role of sinoscopy in the investigation of dental disease is to rule out other causes of paranasal sinusitis. Sinoscopy enables the interior of the paranasal sinuses to be visualized, aiding in the diagnosis of many conditions of the paranasal sinuses, such as primary sinusitis and the presence of a mass.

Most of the structures within the paranasal sinuses can be examined endoscopically, using a flexible, video- or fiberoptic endoscope with the horse standing. Although a rigid arthroscope can also be used, it provides an inferior field of view because it is unable to navigate around structures such as the infra-orbital canal, making good visualization of some structures within the sinuses difficult.

In preparation for sinoscopy, the horse is restrained in a stock and sedated, usually with detomidine (0.01–0.02 mg/kg, IV or 0.03–0.04 mg/kg, IM) or xylazine (0.5–1.0 mg/kg, IV or IM) and butorphanol tartrate (0.02–0.05 mg/kg, IV) or morphine (0.15 mg/kg, IV; see Ch. 15, Restraint and anesthesia). After the horse is sedated, its head can be supported on a stand or small table so that the site for trephination is at a comfortable level for the surgeon. The sites at which the endoscopic portals are to be created are prepared for surgery and desensitized by subcutaneous instillation of 2–3 ml of local anesthetic solution. A portal for insertion of the endoscope is created through a 2- to 3-cm, longitudinal, skin and periosteal incision. A portal through the frontal or maxillary bone created with a 3/8-inch (9.5-mm) to 5/8-inch (1.6-cm) Galt trephine or drill bit accommodates the insertion tube of most endoscopes and allows for quick retrieval of the endoscope, if necessary (Fig. 14.6). The cutaneous incision is sutured or stapled after sinoscopy has been completed. The periosteum is left unsutured.

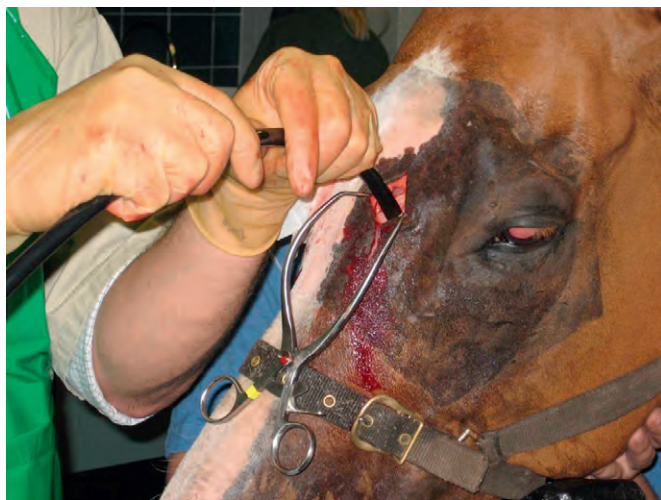


Fig. 14.6 Sinoscopy performed through a conchofrontal approach.

Most of the paranasal sinuses can be examined through a portal through the frontal bone into the conchofrontal sinus (i.e., the frontal and dorsal conchal sinuses) or through a portal through the maxillary bone into the caudal maxillary sinus. A portal into the conchofrontal sinus generally provides the best visualization of the conchofrontal and caudal maxillary sinuses. The incision for a portal into the conchofrontal sinus is centered over the frontomaxillary aperture at a site one-third of the distance from the medial canthus of the eye to the dorsal midline, and 0.5 cm caudal to a plane connecting the medial canthi (Fig. 14.6).² The incision for a portal into the caudal maxillary sinus is centered 2 cm ventral and 2 cm rostral to the medial canthus of the eye.²

To evaluate the rostral maxillary and ventral conchal sinuses from either the conchofrontal or the caudal maxillary portal, the bulla of the ventral conchal sinus must be fenestrated under endoscopic guidance, using an arthroscopic rongeur or crocodile forceps passed through the same portal as the endoscope (Figs 14.7 & 14.8).¹³ Hemorrhage is a minor, but not an infrequent complication of fenestrating the bulla. If hemorrhage obscures visualization, sinuscopy should be repeated when hemorrhage has ceased or been evacuated using suction.

The rostral maxillary sinus can also be examined through a portal created in the maxillary bone directly over the rostral or the caudal aspect of the sinus,^{2,5} although this procedure is not without risk of damaging a normal tooth in young horses (i.e., <5 years old), due to the small size of this sinus and its anatomic variability among horses. The skin incision for a rostral portal into the rostral maxillary sinus is oriented longitudinal to the long axis of the head and is created 3 cm caudal to the infraorbital foramen and 1 cm ventral to an imaginary line joining the infraorbital foramen and the medial canthus of the eye.² The skin incision for a caudal portal into the rostral maxillary sinus is centered at a point midway between the rostral end of the facial crest and a point on the facial crest at the level of the medial canthus of the eye, 1 cm ventral to an imaginary line drawn between the infraorbital foramen and the medial canthus of the eye.² Access to the ventral conchal sinus through either portal is

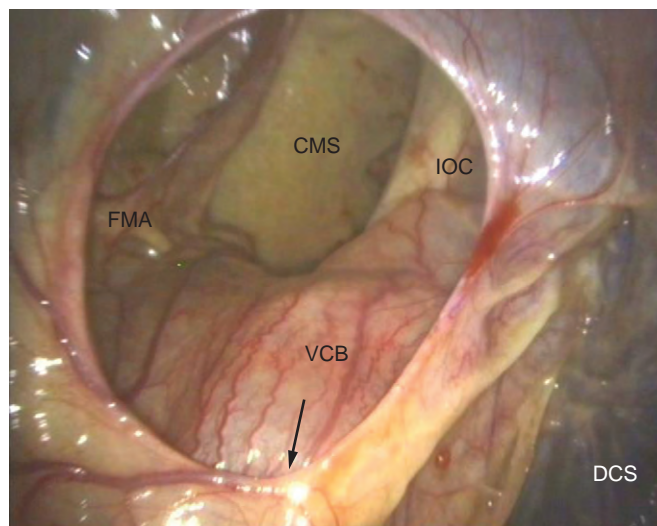


Fig. 14.7 Sinoscopic view of the right conchofrontal sinus. CMS, caudal maxillary sinus; FMA, frontomaxillary aperture; IOC, infraorbital canal; VCB, ventral conchal bulla; DCS, dorsal conchal sinus. The arrow points to the entrance of the intra-sinus, nasomaxillary aperture of the caudal maxillary sinus.

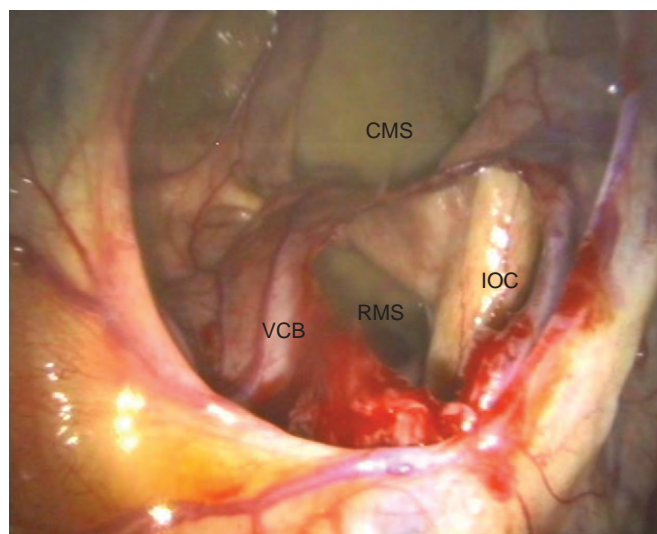


Fig. 14.8 Sinoscopic view of the right conchofrontal sinus (the same as in Fig. 14.7) after endoscopic-guided fenestration of the ventral conchal bulla. CMS, caudal maxillary sinus; IOC, infraorbital canal; VCB, ventral conchal bulla (fenestrated); RMS, rostral maxillary sinus.

poor, and visualization of the rostral maxillary sinus is reduced in comparison to that obtained through a portal into the conchofrontal sinus combined with fenestration of the bulla of the ventral conchal sinus.

Care should be taken when creating a portal into the rostral maxillary sinus to avoid damaging the reserve crowns of the teeth contained within. Damage to the underlying apices is more likely when creating the rostrally positioned portal into the rostral maxillary sinus than when creating a caudally positioned portal,^{2,14} and therefore, the rostrally positioned portal should be used only on horses aged 6 years

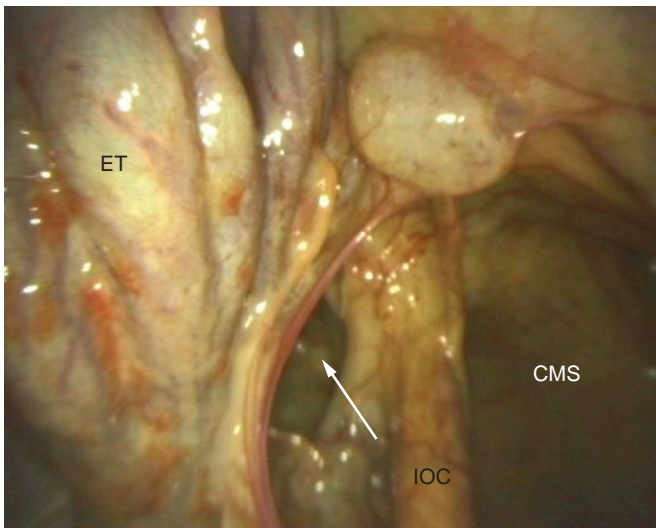


Fig. 14.9 Sinoscopic view in the left caudal maxillary sinus showing the entrance to the sphenopalatine sinus (arrow). ET, intra-sinus portion of the ethmoidal turbinates; CMS, caudal maxillary sinus; IOC, infraorbital canal.

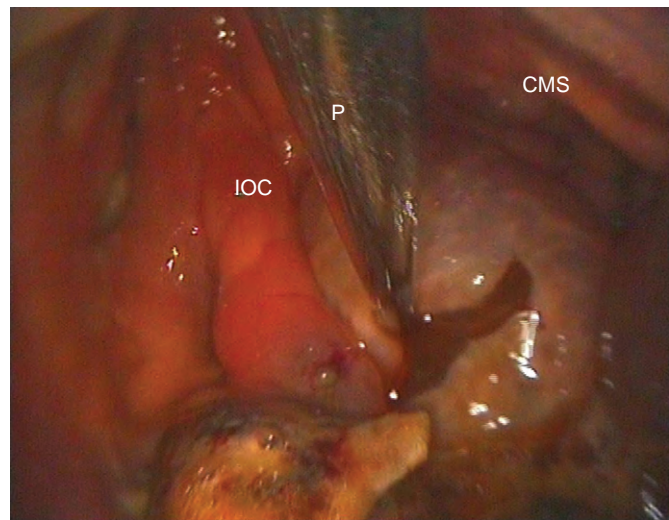


Fig. 14.10 Sinoscopic view of the left caudal maxillary sinus showing edema of the mucosa overlying an apical infection of the 5th maxillary cheek tooth (probe). CMS, caudal maxillary sinus; IOC, infraorbital canal.

or older.¹⁴ Damage to an apex of a cheek tooth is unlikely when using a conchofrontal or caudal maxillary approach.

The respiratory mucosa of the paranasal sinuses should be pink, and its vasculature should be visible. The sinuses should contain little or no fluid. The presence of purulent exudate, even a small amount, is abnormal. If visualizing structures within the paranasal sinuses is difficult because a large volume of exudate is present within the sinuses, the sinuses should be lavaged with normal saline solution once or twice daily for one or two days before sinuscopy is performed.

The interior of the conchofrontal and caudal maxillary sinuses can be visualized directly through the portal in the frontal bone. Structures that can be identified within the conchofrontal sinus include the scroll-like surface of the ethmoturbinates, located at the caudomedial aspect of the frontal sinus, and the frontomaxillary aperture located directly below the endoscopic portal (Fig. 14.7). Structures observed within the caudal maxillary sinus include the maxillary septum, which marks the rostral boundary of the caudal maxillary sinus; the opening of the nasomaxillary aperture, formed by floor of the dorsal conchal sinus and maxillary septum, at the rostral aspect of the frontomaxillary aperture; the apices of the 5th and 6th cheek teeth (Triadan 10 and 11); the infraorbital canal coursing caudally from the caudal aspect of the caudal maxillary sinus to the maxillary septum; and the entrance of the sphenopalatine sinus medial to the caudal aspect of the infraorbital canal (Fig. 14.9).

These same structures can also be observed through the portal into the caudal maxillary sinus created in the maxillary bone ventral to the eye, but visualization of some structures in the ventral conchal sinus and the rostral maxillary sinus, such as the apices of the 3rd and 4th cheek teeth (Triadan 08 and 09) and the entrance of the sphenopalatine sinus, is more difficult.

Structures that can be observed through the portals into the rostral maxillary sinus created in the maxillary bone

include the apex of the 4th cheek tooth (Triadan 09) and a portion of the 3rd and 5th cheek teeth (Triadan 08 and 10), the long, slit-like conchomaxillary aperture (i.e., the entrance to the ventral conchal sinus), and occasionally, the rostromaxillary portion of the nasomaxillary aperture. Visualization of the apices of the 3rd and 4th cheek teeth (Triadan 08 and 09) through either of the portals in the maxillary bone into the rostral maxillary sinus is comparable to that achieved through the conchofrontal portal. Because of its small size, the rostral maxillary sinus is more difficult to evaluate endoscopically than are the caudal maxillary and conchofrontal sinuses. The rostral maxillary sinus of young horses is especially difficult to evaluate because the reserve crowns of the 3rd, 4th, and 5th cheek teeth (Triadan 08–10) occupy most of the sinus. The size of the maxillary sinuses increases, and the apices of the cheek teeth become less prominent as horses age because of the perpetual extrusion and rostral migration of the reserve crowns of the cheek teeth.

Sinoscopic findings specific to dental sinusitis include a swollen and hyperemic apex of an alveolus (Figs 14.10 & 14.11), an orosinus fistula (Fig. 14.12), food material within the sinuses (Fig. 14.13), and an apical granuloma (Fig. 14.14). Mycotic sinusitis can be primary, or it can occur secondary to chronic bacterial sinusitis, such as that caused by apical infection of a cheek tooth. It can also occur after sinonasal fenestration (Fig. 14.15).^{7,11} Findings during sinuscopy, such as generalized mucosal thickening and edema, petechial hemorrhages, and inspissated exudate, are frequently non-specific, and although confirming the presence of sinusitis, do not allow determination of its cause (Fig. 14.16). Other diagnostic modalities, such as radiography,^{1,15} scintigraphy,¹⁶ and computed tomography,¹⁷ as discussed in detail in Chapter 13, are often required to confirm a diagnosis of dental sinusitis. Because dental sinusitis is frequently chronic, the mucosa is often grossly thickened,¹⁸ preventing accurate identification of the affected tooth by sinuscopy.

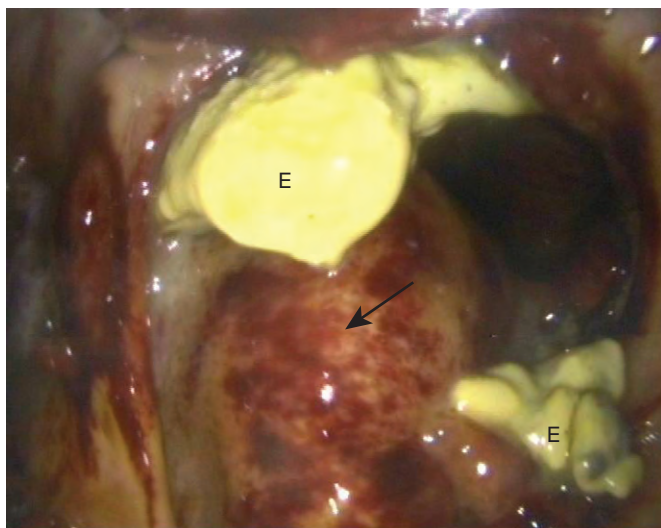


Fig. 14.11 Sinoscopic view of the rostral maxillary sinus, after fenestration of the ventral conchal bulla, showing edema of the mucosa overlying an apically infected 4th maxillary cheek tooth (arrow) and exudate (E) associated with the infection.

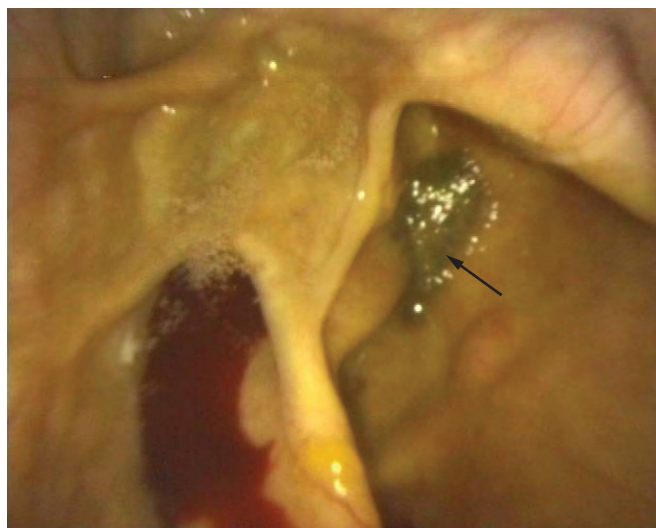


Fig. 14.13 Sinoscopic view of the rostral maxillary sinus after fenestration of the ventral conchal bulla of a horse with an oro-sinus fistula. The rostral maxillary sinus contains small amounts of food (arrow).

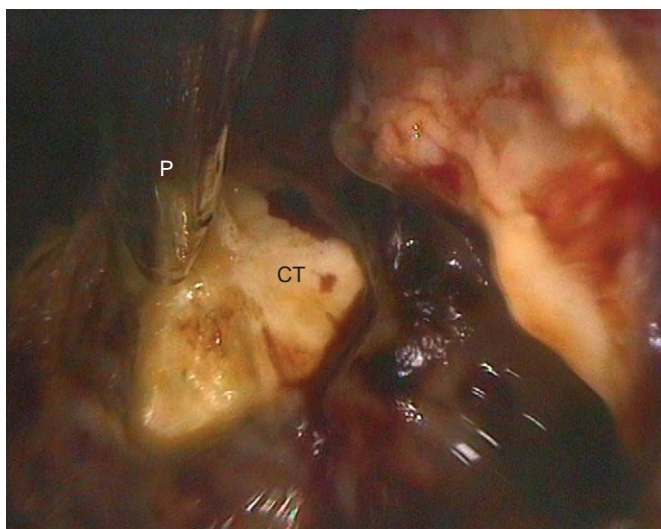


Fig. 14.12 Sinoscopic view into the rostral maxillary sinus after fenestration of the ventral conchal bulla. The probe (P) is placed on the apex of the 4th maxillary cheek tooth (CT). The overlying alveolar bone has been eroded. A chronic oro-sinus fistula (not seen in this view) provided a direct channel for food to enter the sinuses.



Fig. 14.14 Sinoscopic view of the left caudal maxillary sinus showing an apical granuloma overlying an apical infection of the 5th maxillary cheek tooth (arrow). CMS, caudal maxillary sinus; IOC, infraorbital canal.

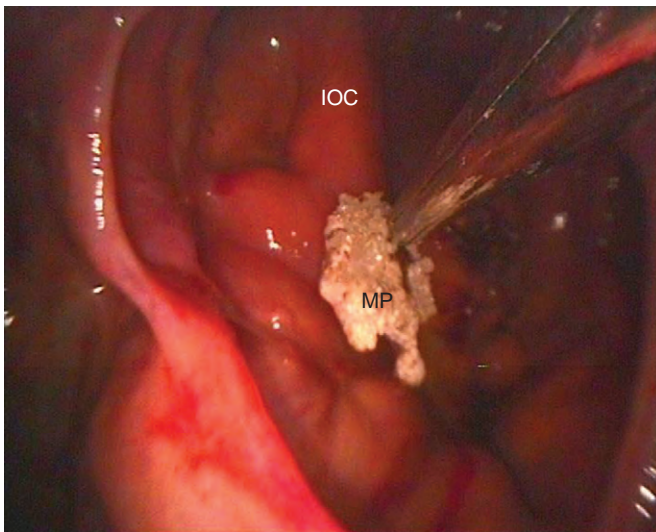


Fig. 14.15 Sinoscopic view of a mycotic plaque (MP) associated with an apical dental infection and chronic sinusitis. IOC, infraorbital canal.

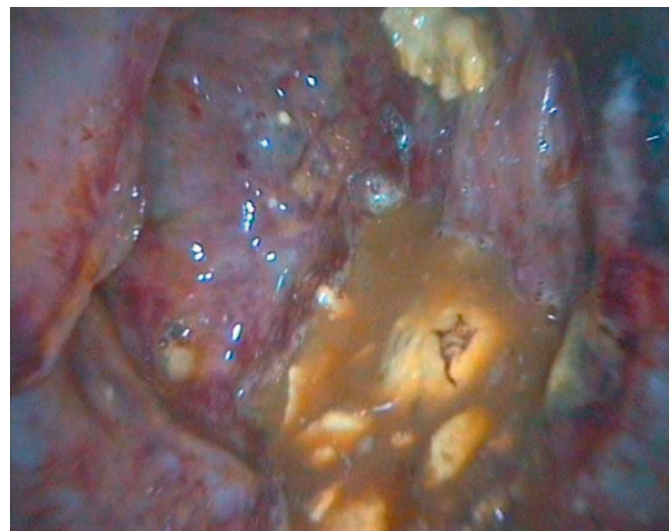


Fig. 14.16 Sinoscopic view of the right caudal maxillary sinus of a horse with chronic sinusitis secondary to apical infection of a maxillary cheek tooth. The mucosa is edematous and contains petechia. Inspissated exudate lies on the floor of the sinus.

References

- Gibbs C, Lane JG. Radiographic investigation of the facial, nasal and paranasal sinus regions of the horse: II. Radiological findings. *Equine Vet J* 1987; 19: 474–492
- Ruggles AJ, Ross MW, Freeman DE. Endoscopic examination of normal paranasal sinuses in horses. *Veterinary Surgery* 1991; 20: 418–423
- Lavery S, Pascoe JR. Sinusitis. In: Robinson NE. *Current therapy in equine medicine*, 4th edn. WB Saunders, Philadelphia, 1997, pp 419–422
- Schumacher J, Honnas C, Smith B. Paranasal sinusitis complicated by inspissated exudate in the ventral conchal sinus. *Veterinary Surgery* 1987; 16: 373–377
- Ruggles AJ, Ross MW, Freeman DE. Endoscopic examination and treatment of paranasal sinus disease in 16 Horses. *Veterinary Surgery* 1993; 22: 508–514
- Mansmann RA, Wheat JD. The diagnosis and treatment of equine upper respiratory diseases. In: *Proceedings of the 18th Annual Convention of the American Association of Equine Practitioners*. Lexington, KY, 1973, pp 388–487
- Tremaine WH, Dixon PM. A long-term study of 277 cases of equine sinonasal disease. Part 1: Details of horses, historical, clinical and ancillary diagnostic findings. *Equine Vet J* 2001; 33: 274–282
- Newton JR, Verheyen K, Talbot NC, et al. Control of strangles outbreaks by isolation of guttural pouch carriers identified using PCR and culture of *Streptococcus equi*. *Equine Vet J* 2000; 32: 515–526
- Mason BJE. Empyema of the equine paranasal sinuses. *Journal of American Veterinary Medical Association* 1975; 167: 727–731
- Mackintosh ME, Colles CM. Anaerobic bacteria associated with abscesses in the horse and donkey. *Equine Vet J* 1987; 19: 360–362
- McGorum BC, Dixon PM, Lawson GHK. A review of ten cases of mycotic rhinitis. *Equine Veterinary Education* 1992; 4: 8–12
- Lane JG. The management of sinus disorders of horses – Part 1. *Equine Veterinary Education* 1993; 5: 5–9
- Freeman DE. Sinus Disease. *Veterinary clinics of North America: equine practice* 2003; 19: 209–243
- Barakzai SZ, Kane-Smyth J, Lowles J, Townsend N. Trephination of the equine rostral maxillary sinus: efficacy and safety of two trephine sites. *Veterinary Surgery* 2008; 37: 278–282
- Wyn-Jones G. Interpreting radiographs 6: Radiology of the equine head (Part 2). *Equine veterinary Journal* 1985; 17: 417–425
- Weller R, Livesey L, Maierl J, et al. Comparison of radiography and scintigraphy in the diagnosis of dental disorders in the horse. *Equine Vet J* 2001; 33: 49–58
- Henninger W, Frame EM, Willmann M, et al. CT features of alveolitis and sinusitis in horses. *Veterinary Radiology and Ultrasound* 2003; 44: 269–276
- Tremaine WH, Clarke CJ, Dixon PM. Histopathological findings in equine sinonasal disorders. *Equine Vet J* 1999; 31: 296–303

Dental restraint and anesthesia

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Sedation

Surgical and diagnostic dental procedures are often performed with the horse sedated because this eliminates the risks associated with general anesthesia. In addition, performing dental procedures with the horse sedated, rather than anesthetized, incurs less expense and time. Problems associated with performing surgical and diagnostic dental procedures with the horse sedated include over-sedation, which can result in excessive ataxia, insufficient analgesia to safely complete the procedure, excessive movement complicating the procedure, and increased risk to personnel. Analgesia can be augmented by administering local or regional anesthesia, but for some procedures, such as extraction of wolf teeth, sedation alone may sometimes be sufficient.

Sedation can be maintained either with bolus injections of a sedative, alone or in combination with an opioid, or by constant rate infusion (CRI) of the sedative, alone or in combination with an opioid. A bolus injection of the sedative is the more common mode of administering sedation. Alpha-2 agonists commonly administered as a bolus include detomidine (0.005–0.02 mg/kg, IV), xylazine (0.3–1.0 mg/kg, IV), medetomidine (0.0035–0.007 mg/kg, IV), and romifidine (0.03–0.1 mg/kg, IV). The duration of sedation achieved by administration of xylazine is short when compared to the duration of sedation imparted by detomidine, medetomidine, or romifidine. When administered intramuscularly, the sedative should be administered at least 15 minutes before surgery, and the dose of the drug should be at least double that of the intravenous dose to achieve the same effect. To minimize movement, the horse can be re-sedated during surgery with the same or another sedative (xylazine [0.5 mg/kg, IV]; detomidine [0.01 mg/kg, IV]; medetomidine [0.002 mg/kg, IV]; or romifidine [0.06 mg/kg, IV]).

Butorphanol (0.02–0.05 mg/kg, IV) is the most common opioid administered in conjunction with a sedative. Other opioids administered include methadone (0.1 mg/kg, IV) and morphine (0.15 mg/kg, IV). Sedation with an alpha-2 agonist should precede administration of the opioid to avoid opioid-induced excitement. Reducing the initial dose of an alpha-2 agonist and administering subsequent doses to effect is prudent to avoid over-sedation when using combinations of drugs. A heavily sedated horse may need the

support of a stocks partition, or wall to prevent it from falling. On some occasions, reversing an alpha-2 agonist to speed the recovery of the horse from sedation may be desirable. This is generally necessary only if a large dose of detomidine or romifidine was administered. Yohimbine (0.15 mg/kg, IV), even though it is a weak antagonist, is usually effective. Alternatively, atipamezole (0.15 mg/kg, IV), a more potent antagonist, can be used as a reversal agent. The antagonist should be infused slowly to diminish the likelihood of the reversal agent causing excitation.

If a long procedure is anticipated, sedation can be maintained at a more constant level using a CRI of one or more sedatives after a loading bolus of the sedative has been administered. Drugs commonly administered by CRI include detomidine alone (0.02 mg/kg/hour) or in combination with either butorphanol (0.012 mg/kg/h) or morphine (0.15 mg/kg/h). To avoid inducing excitement when using an opioid in combination with an alpha-2 agonist, a loading dose of the alpha-2 agonist (e.g., detomidine [0.008 mg/kg]) should be administered initially before a loading dose of butorphanol (0.02 mg/kg) or morphine (0.15 mg/kg) is administered.

Nerve blocks of the head

The portion of the head subjected to a dental procedure can be desensitized by using a regional nerve block. Regional nerve blocks of the head include the maxillary, infraorbital, mandibular, mandibular alveolar, and mental nerve blocks. A regional nerve block is administered most easily after the horse has been sedated, and administering the block with the horse sedated enhances the safety of the horse and the operator. Application of a nose twitch often facilitates administration of the block.

Maxillary nerve block

Anesthetizing the maxillary nerve at the pterygopalatine fossa, where the nerve enters the infraorbital canal to become the infraorbital nerve, desensitizes all the ipsilateral dental structures of the maxilla and premaxilla, the paranasal sinuses, and nasal cavity. To anesthetize the maxillary nerve at the pterygopalatine fossa, the point of a 20- to 22-gauge, 3.5 inch (8.9 cm), spinal needle is inserted just ventral to



Fig. 15.1 The maxillary nerve can be anesthetized at the pterygopalatine fossa, by inserting a 20- to 22-gauge, 3.5-inch (8.9 cm), spinal needle just ventral to the zygomatic process and dorsal to the transverse facial vessels at the level of the caudal third of the orbit. 15–20 ml of local anesthetic solution is deposited after the needle strikes bone.



Fig. 15.2 The maxillary nerve can be anesthetized at the pterygopalatine fossa by inserting a 6-inch (15.2-cm) needle ventral to the most dorsal aspect of the zygomatic process and directing the needle rostrally and ventrally, aiming toward the rostral edge of the contralateral facial crest, until the needle strikes bone.

the zygomatic process and dorsal to the transverse facial vessels at the level of the caudal third of the orbit (Fig. 15.1).¹ The tip of the needle is inserted perpendicular to the longitudinal axis of the head so that it enters the pterygopalatine fossa just caudal to the maxillary tuberosity at a depth of approximately 2–2.5 inches (5.0–6.5 cm). The horse may jerk its head if the tip of the needle contacts the nerve. An alternative method of anesthetizing the maxillary nerve at the pterygopalatine fossa is to insert the point of a 6 inch (15.2 cm) needle ventral to the most dorsal aspect of zygomatic process, directing the needle rostrally and ventrally, aiming toward the rostral edge of the contralateral facial crest, until the needle strikes bone (Fig. 15.2).

Regardless of the technique used, 15 to 20 ml of local anesthetic solution is instilled after the needle strikes bone and as the needle is withdrawn slightly. Structures innervated by the maxillary nerve are desensitized within 15 minutes.



Fig. 15.3 The infraorbital foramen is located by placing a thumb (or middle finger) in the notch formed by the nasal bone and premaxilla and the middle finger (or thumb) on the rostral aspect of the facial crest. The foramen can be palpated with the index finger halfway between 1 and 3 cm caudal to an imaginary line connecting the thumb and middle finger after elevating the ventral margin of levator labii superioris muscle with the index finger.

Infraorbital nerve block

The infraorbital nerve block is useful for performing surgery of the nose or maxillary and premaxillary dental structures. When the infraorbital nerve is anesthetized rostral to the infraorbital foramen, where it emerges from the infraorbital canal, the area desensitized includes the skin of the ipsilateral lip, nostril, and face, up to the level of the infraorbital foramen. When the infraorbital nerve is anesthetized within the infraorbital canal, additional structures desensitized include the ipsilateral maxillary and premaxillary teeth, and associated alveoli and gingiva. The effect is the same as that achieved with a maxillary nerve block, provided that the local anesthetic solution completely fills the infraorbital canal.

To locate the infraorbital foramen, a thumb (or middle finger) is placed in the notch formed by the nasal bone and premaxilla, and the middle finger (or thumb) is placed on the rostral aspect of the facial crest. The foramen is located with the index finger halfway between and 1 to 3 cm caudal to an imaginary line connecting the thumb and middle finger (Fig. 15.3). The ridge of the foramen is palpated beneath the ventral margin of the levator labii superioris muscle. To anesthetize the infraorbital nerve within the infraorbital canal, a 21- or 22-gauge, 1½-inch (3.8-cm) needle is inserted through the skin about ½ inch (1.3 cm) rostral to the foramen after elevating the ventral edge of the levator labii superioris muscle. The point of the needle is advanced along the surface of the maxilla and inserted about 1 inch (2.5 cm) into the canal. Four to 8 ml of local anesthetic solution is deposited within the canal.



Fig. 15.4 (A) To anesthetize the mandibular nerve, a 20- to 22-gauge, 6–8-inch (15.2–20.3-cm) spinal needle is inserted at the ventral border of the ramus, just rostral to the angle of the mandible and aimed dorsally, along the medial aspect of the vertical ramus of the mandible, toward the mandibular foramen. 15–20 ml of local anesthetic solution is deposited. (B) The mandibular foramen is located at a point where an imaginary line that extends along and caudal to the occlusal surface of the mandibular cheek teeth intersects with another imaginary line that passes from the lateral canthus of the eye perpendicular to the first line.

Filling the infraorbital canal with a large volume of local anesthetic solution likely desensitizes all the same structures that the maxillary nerve block desensitizes because the local anesthetic solution anesthetizes the infraorbital nerve as far caudally as the maxillary foramen. The advantage of the infraorbital nerve block over the maxillary nerve block is that instilling local anesthetic solution within the infraorbital canal assures that the infraorbital nerve has been anesthetized. The infraorbital nerve block is tolerated poorly by the horse, however, because the point of the needle inevitably contacts the infraorbital nerve directly, so adequate restraint and great care should be taken during its administration.

Mandibular nerve block

Anesthetizing the mandibular nerve at the mandibular foramen, where it enters the mandibular canal to become the mandibular alveolar nerve, desensitizes the ipsilateral side of the mandible and all its dental structures. The mandibular foramen is located on the medial aspect of the vertical ramus of the mandible where an imaginary line that extends along and caudal to the occlusal surface of the mandibular cheek teeth intersects with another imaginary line that passes perpendicular to the first line from the lateral canthus of the eye. To anesthetize the mandibular nerve, the point of a 20- to 22-gauge, 6–8-inch (15.2–20.3-cm) spinal needle is inserted at the ventral border of the ramus, just rostral to the angle of the mandible and aimed dorsally (Fig. 15.4), or a 3½-inch (8.9-cm) spinal needle is inserted at the angle formed by the intersection of the vertical and horizontal rami of the mandible and aimed rostrally and dorsally (Fig. 15.5). The point of the needle is advanced along the medial surface of the ramus toward the mandibular foramen, and 15 to 20 ml of local anesthetic solution is deposited.

Inserting the needle to a point slightly dorsal to the estimated location of the foramen helps to ensure that local anesthetic solution contacts the mandibular nerve because the nerve courses ventrally from a dorsal location to enter



Fig. 15.5 To anesthetize the mandibular nerve, a 3½ inch (8.9 cm) spinal needle is inserted along the medial surface of the vertical ramus of the mandible at the angle formed by the intersection of the vertical and horizontal rami and aimed rostrally and dorsally toward the mandibular foramen, the location of which is described in the legend for Fig. 15.4.

the foramen. A second needle of the same length applied to the lateral surface of the mandible can be used to judge the depth of the insertion of the first needle. Structures innervated by the mandibular nerve are desensitized within 15–30 minutes.

Mental nerve block

The mandibular alveolar nerve traverses the mandibular canal to emerge at the mental foramen as the mental nerve. Anesthetizing the mental nerve rostral to where it exits the mental foramen desensitizes the skin of the ipsilateral lip and chin. The mandibular canine, incisor, and cheek teeth and associated alveoli and gingiva are innervated by branches of the mandibular alveolar nerve, which lie within the mandibular canal, and so, to desensitize these structures, local



Fig. 15.6 The mental foramen can be palpated with an index finger on the lateral aspect of the horizontal ramus of the mandible in the interalveolar space directly below the commissure of the lips by elevating the tendon of the depressor labii inferioris muscle with the index finger. To anesthetize the mandibular alveolar nerve, a 21- or 22-gauge, 1½-inch (3.8-cm) needle is inserted into the mandibular canal about ½ inch (1.3 cm) rostral to the mental foramen after elevating the tendon of the depressor labii inferioris muscle.

anesthetic solution must be instilled into the mandibular canal. Anesthetizing either the mental nerve at the mental foramen or the mandibular alveolar nerve within the mandibular canal is termed a mental nerve block.

The mental foramen is located on the lateral aspect of the horizontal ramus of the mandible in the interalveolar space directly below the commissure of the lips (Fig. 15.6). The mental foramen lies beneath the tendon of the depressor labii inferioris muscle, and so to palpate the ridge of the mental foramen, this tendon must be elevated dorsally. To anesthetize the mandibular alveolar nerve within the rostral aspect of the mandibular canal, a 21- or 22-gauge, 1½-inch (3.8-cm) needle is inserted through the skin about ½ inch (1.3 cm) rostral to the mental foramen after elevating the tendon of the depressor labii inferioris muscle. Creating a bend in the shaft of the needle aids its insertion. The needle is inserted into the mandibular canal as far as possible, and 5–10 ml of anesthetic solution is deposited.

Filling the mandibular canal with a large volume of local anesthetic solution (i.e., >10 ml) likely desensitizes all the same structures that the mandibular nerve block desensitizes because the local anesthetic solution anesthetizes the mandibular alveolar nerve as far caudally as the mandibular foramen. The mental nerve block is tolerated poorly by the horse because the point of the needle inevitably contacts the mandibular alveolar nerve directly.



Fig. 15.7 The site of centesis of the caudal pouch of the dorsal compartment of the TM joint is located midway between ¼ and ½ inch (0.64–1.3 cm) caudal to an imaginary line connecting the mandibular condyle and the zygomatic process. The needle is inserted in a rostral and ventral direction to a depth of about 1 inch (2.5 cm), and 2–3 ml of local anesthetic solution is infused into the pouch.

Analgesia of the temporomandibular joint

Analgesia of the temporomandibular (TM) joint is sometimes used for diagnostic purposes, e.g., to determine if a TM joint is infected or if disease of one or both TM joints could be the cause of clinical signs of disease displayed by the horse. The TM joint is the articulation between the base of the zygomatic process of the temporal bone and the mandibular condyle of the mandible.² A fibrocartilaginous disc separates the joint into a large, dorsal compartment, with a rostral and caudal pouch, and a smaller ventral compartment. Whether or not the dorsal and ventral compartments communicate is disputed.^{2,3}

The mandibular condyle is palpated as a smooth protrusion approximately midway between the base of the ear and the lateral canthus of the eye. Its identity can be confirmed by palpating the protrusion while an assistant moves the mandible. The zygomatic process of the temporal bone is identified several centimeters dorsal to the mandibular condyle. The site of centesis of the caudal pouch of the dorsal compartment is located midway between and ¼ to ½ inch (0.64 to 1.3 cm) caudal to an imaginary line connecting these structures (Fig. 15.7).³ The needle is inserted at this site, with the horse sedated, in a rostral and ventral direction to a depth of about 1 inch (2.5 cm). Fluid may fill the hub of the needle when the needle is inserted into the pouch. The pouch is infused with 2–3 ml of local anesthetic solution. Even if the dorsal and ventral compartments do not communicate, the local anesthetic solution likely diffuses into the ventral compartment in sufficient concentration to provide analgesia of structures contained within that compartment.

References

1. Fletcher BW. How to perform effective equine dental nerve blocks. In Proceedings, 50th Annual Convention of American Association of Equine Practitioners 2004; 233–236
2. Weller R, Taylor S, Maierl J, et al. Ultrasonographic anatomy of the equine temporomandibular joint. *Equine Vet J* 1999; 31: 529–532
3. Rosenstein DS, Bullock ME, Ocello PJ, et al. Arthrocentesis of the temporomandibular joint in adult horses. *Am J Vet Res* 2001; 62: 729–733

Equine dental equipment, supplies and instrumentation

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Introduction

Practitioners interested in equine dentistry have much to be excited about. New equipment, equipment enhancements, improved techniques in diagnosing and treating equine dental disease, and many avenues for advanced instruction, have encouraged more equine veterinary practitioners to emphasize dental care. The care, safety, and pain control for the patient, as well as the safety and comfort of the caregivers, are ongoing priorities.

Work location and patient restraint

When possible, horses should be handled in a dry, enclosed area protected from weather. Dentistry can be done outside, but proper patient restraint is essential. Outside work areas should be free of obstacles, clutter and other animals. Shading is important for easier visualization of the oral cavity, but if shading is unavailable, position the caregiver with the sun shining from behind. Stocks provide an extra measure of safety whether working indoors or out (Fig. 16.1A&B). Water and electricity should be readily available. Observers should be kept at a safe distance while work is performed, then allowed to view the results up close. Avoid having owners hold their own horses, if possible.

Working in a familiar area, such as the horse's stall, creates less anxiety for the animal. It is preferable for work areas to have three solid sides. Avoid low-ceilinged and narrow spaces in case the horse should rear or go down. Footing should be non-slip when wet, and easy to drain. Buckets and extraneous items should be out of the way. Horses can be attended to inside a stall, either backed into a corner or standing in the stall doorway. When working in a stall, dental equipment and supplies must be transported from stall to stall, so a portable workstation is a handy investment to hold small instruments, mirrors, and other essential equipment (Figs 16.2 & 16.3). However, the preferred approach is to work from one location, such as in the grooming, farrier, or wash area.

Special mobile dental workstations constructed around stocks or horse trailers have been developed in recent years.

Some practitioners have designed fully-contained dental trailers with all equipment close by, including radiography and a computer workstation (Fig. 16.4). A well equipped, climate-controlled dental trailer is ideal for having equipment immediately at hand, but can be expensive. Each new patient has to be moved in and out of the trailer stocks. Nervous horses may have to be lightly sedated prior to entry and alpha-2 agonist reversal agents have to be administered to avoid a long post-dental period waiting for a heavily sedated horse to recover sufficiently to walk safely back to the stall.¹ (See Ch. 15.)

Several types of portable restraint systems that can be easily towed behind a vehicle are available. Most are hydraulically adjusted and very suitable to perform dental work. When working in stocks, equipment should be modified for safety and ease of use. The front door of the stocks should not be more than 1 m high to allow the relaxed, sedated horse to drop its head without compressing its trachea on the door. A butt rope or adjustable rear gate helps keep the horse positioned in the front of the stocks.² A head stand or suspended dental halter is required for heavily sedated horses. Having a 10–20-cm overhead extension on the stocks helps keep the suspended dental halter properly positioned in front of the stocks. An elevated step may be placed in the stocks when working on ponies or miniature horses.³ An adjustable rolling stool is preferable when using stocks because it helps maintain proper posture for the caregiver, keeping one's back straight while allowing the arms to remain lower than the shoulders. If a rolling mechanics stool is not available, knee pads are recommended for working on the floor in front of the stocks.

Head stands and dental suspension halters

Dental head supports and head stands vary in cost and complexity, and come in many styles – from a homemade padded PVC pipe or padded crutch to power-adjustable aluminum stands (Fig. 16.5) (Box 16.1). All require an assistant to stabilize the head on the support. (Note: avoid using someone's shoulder to prop up the head.)

Manufactured head stands have several advantages that include rapid adjustment of height, good stability, and



Fig. 16.1 Portable horses' stocks or crush. (A) This stocks pulls in-line behind a vehicle. The chest and butt bars, head stand, and sides are hydraulically adjustable. (B) This stocks pulls on its side and is rotated off its trailer for setup. The extended overhead bar attached to the suspension halter keeps the head stable with the mouth speculum in place.

often, heavy padding, as well as a washable cover on which the mandible can rest.⁴ Many stands are designed with attachments for holding equipment and dental instruments.

There are a variety of manufactured, rigid dental halters available. However, practitioners themselves are quite inventive in developing restraint devices and homemade halters, depending on individual preference and need. The full-mouth speculum used may determine the type of rigid halter used, as the larger specula do not fit inside some rigid halters. Some mouth specula have been modified to accommodate suspension devices by incorporating a metal arch over the nose piece of the speculum for rope attachment (Fig. 16.6). Suspending the head with the speculum nose band is convenient, but if the horse moves rearward, the speculum can be pulled off the head and/or the poll can be over-extended. This can damage incisors,



Fig. 16.2 Portable folding aluminum table used to transport dental instruments from stall to stall.



Fig. 16.3 An electric golf cart converted to a mobile equine dental station (T.A. Banner, DVM, Gainesville, FL, USA).

especially in geriatric horses. Suspending the head with two ropes provides greater stability, but a practitioner working with few assistants may find a single rope with a quick release device more manageable. For more restraint and handling recommendations, consult Chapters 12, 15, 17, and 18.

Oral examination equipment (Box 16.2)

Various types of equipment may be used to conduct a thorough dental examination. The horse's overall health status should be evaluated, and a stethoscope and thermometer should be available. Continuing the examination process, the mouth must be held open to allow a complete visual and digital examination. A halter with an oversized nose band allows the horse to fully open its mouth for inspection and treatment.

A bucket is needed to hold floats and disinfectant. Stainless steel is the usual veterinary choice, but plastic has its



Fig. 16.4 (A) Fully functional equine dental trailer designed to transport equipment and service as a climate controlled workstation with warm water and electricity. (B) Loading end of a dental trailer complete with adjustable stocks. (C) Interior of dental trailer with horse in stocks. The mouth is open and head stabilized on a stand. The operator is seated in a comfortable position to perform dental work.



Fig. 16.5 Three types of equine head stands. Left: adjustable floor stand with a flat removable padded chin rest. Middle: support with flexible base and side bars to help keep the chin on the stand. Right: adjustable floor stand with base at an angle to chin support and down-turned corners for added stability.

advantages: for example, using a plastic bucket results in less noise when an instrument is dropped into the bucket. Some practitioners place a rubber insert on the bottom of the stainless steel bucket to cushion the instruments. Many instrument companies offer a variety of

guards, restrainers, or liners for float blade protection (Fig. 16.7). Using a tray or table, rather than dropping small instruments into a bucket, prevents breakage and dulling sharp edges of expensive and brittle tungsten carbide float blades.



Fig. 16.6 McPherson type speculum. This is the most popular and least expensive type of equine speculum. The stainless steel models are more durable and easier to clean than the nickel-plated cast iron devices. A metal nose bar has been added for attachment to a rope to suspend the head from an overhead support. The ratchet on this type of speculum has limited adjustments and can be difficult to open. The hinge is close to the incisor plates (18–20 cm) and does not allow a comfortable fit for large breed horses (over 800 kg). This speculum comes in a small size for ponies and miniature horses. Various incisor and gum plates are available, which makes it quite versatile for use in horses with incisor damage or malocclusions.

Box 16.1 Head support and head stand suggestions

- All types should be well padded
- Flat square supports are more stable in holding the head upright because more of the mandible contacts the support
- The head support should not limit or interfere with mouth access
- The speculum must fit inside a suspended support
- The stand should have a stable base
- Suspended supports should have quick adjustment and release mechanisms
- The stand can be modified to hold floats with multiple attachments

Box 16.2 Basic dental equipment

- Stethoscope and thermometer
- Head support when heavy sedation is used
- Examination gloves
- Bucket and disinfectant
- Dose syringe or oral irrigator
- Full-mouth speculum
- Arcade speculum
- Bright light source
- Calipers or clear ruler marked in millimeters for measurement of molar excursion
- Assorted dental picks and probes to examine gingival attachment, periodontal pockets, and infundibula and pulp horns
- Retractors
- Dental mirror
- Small digital camera
- Form to record findings



Fig. 16.7 Stainless steel bucket with a rubber lined bottom. PVC tube liners separate and protect float blades.

Sanitation

Chlorhexidine gluconate 0.05 % (1–40 dilution of the 2 % concentration) is the antiseptic of choice for oral rinses and has replaced chlorhexidine acetate because it is less likely to irritate mucous membranes. Although it is rare, horses may develop anorexia from chlorhexidine use. Since it may be the taste of chlorhexidine causing the anorexia, a human product such as Periogard (a Colgate rinse) may prevent this adverse effect. Periogard and other flavored chlorhexidine rinses are 0.12 % chlorhexidine. Some practitioners use two buckets, both containing diluted chlorhexidine: one bucket is for instrument immersion and the other is solely for rinsing the patient's mouth. Instruments should be cleaned between horses and sanitized between groups of animals or farms.

Latex or nitrile gloves should be worn for protection during all oral examinations and treatments. Nitrile is more resistant to puncture, but when it does fail, there is an obvious hole rather than an unnoticed pinhole. Changing gloves between each horse is probably not needed in healthy horses grouped together, but it is recommended after working on any horse with active periodontitis or suspected infectious respiratory disease. Wearing gloves reduces the number and severity of cuts and abrasions caused by sharp enamel projections or the handling of rasping instruments. Practitioners should carry a hand brush, medicated soap or disinfectant, and a towel to clean their hands and finger nails, as well.

Oral irrigation equipment

Large dose syringes are widely used to rinse mouths and are available with either a pistol grip or in a plunger style. The

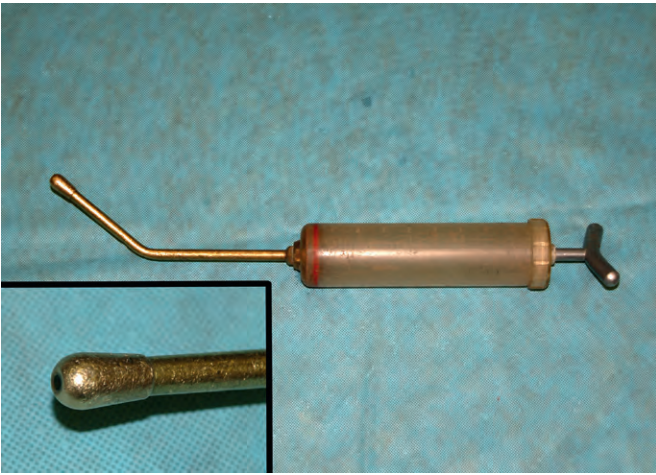


Fig. 16.8 Nylon 400 cc, blunt tipped, dosing syringe used to flush the mouth prior to oral examination.

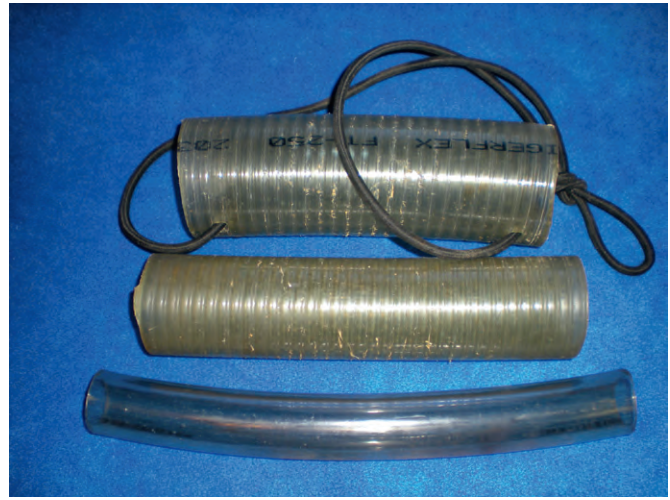


Fig. 16.10 Three diameters of heavy duty plastic tubing. The tube is placed in the interdental space as a gag when working on incisor teeth.

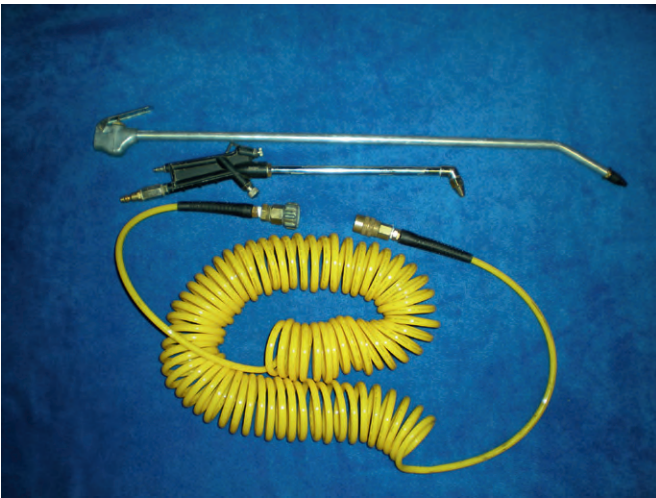


Fig. 16.9 Oral irrigation unit with two types of nozzles modified to attach to any water outlet. This unit was fabricated from mechanic compressed air blower parts.

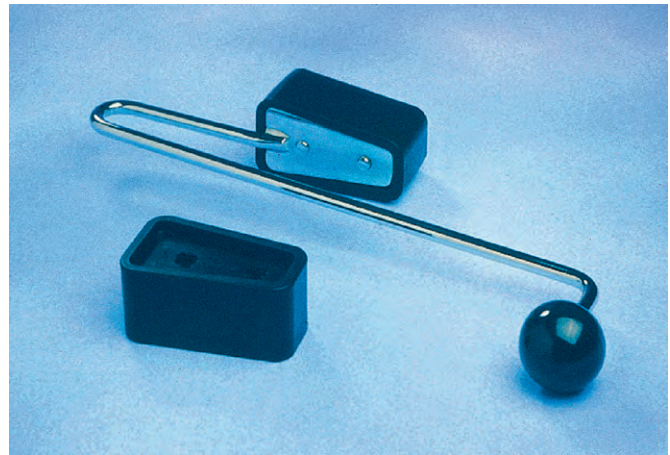


Fig. 16.11 One-sided, wedge-shaped mouth gag made from a block of neoprene. This type of gag is safe for use while working on the incisor teeth.

patient's mouth should be rinsed prior to the intra-oral portions of the dental examination in order to facilitate proper visualization of the teeth and associated soft tissues. The rounded blunt end of the nozzle on the large nylon dose syringe helps prevent accidental oral injury during flushing (Fig. 16.8). A 16 oz dose syringe is sufficient for removing food from the mouth, but a powerful spray is needed for rinsing periodontal pockets or an alveolus post extraction. A high-pressure rinse can be administered with instruments like a power dental flush, which attaches directly to a hose. Commercial high-pressure units are available or can be made from parts available in the air compressor section of large home supply stores (Fig. 16.9).

Specula

Several types of gags and specula can be used to visually and manually evaluate the mouth. These instruments work via

insertion into the mouth between the incisors, upper and lower bars, or cheek teeth arcades. Two types of specula are needed: 1) a gag for incisor procedures and 2) a full-mouth speculum for cheek teeth examination and equilibration.

The use of gags should be confined to the treatment of the incisor teeth. Gags that sit between the bars are easily made from heavy-duty rubber or plastic tubing available at large home supply stores. Three diameter sizes are needed (3.81 cm, 5.08–5.715 cm, and 7.62 cm) and should be cut to the desired length. An elastic cord is to be attached to each end of the tube. The tube is slipped into the interdental space and the cord over the poll. Most horses tolerate this well when adequately sedated (Fig. 16.10).

One-sided metal gags inserted between the cheek teeth, especially the round Schoupe coil or spool, are not recommended because they may fracture a tooth. Wedge-shaped gags may be covered with rubber, polyurethane or neoprene, or may simply consist of metal (Fig. 16.11). Such gags are safer than spool or coil gags as they allow several teeth to contact the wedge simultaneously. There are disadvantages



Fig. 16.12 Series 2020 full-mouth speculum with small interchangeable ratchets for easy opening. A wide range of incisor and gum plates are available for this speculum.



Fig. 16.13 Capps full-mouth speculum with infinite adjustments and interchangeable incisor plates. This speculum works well on large breed horses.

with gags – there is limited access to the mouth, the horse continually chews on them, and they are difficult to keep in place.

Full-mouth specula are especially helpful in performing both complete, detailed dental examinations and precise corrective procedures. All full-mouth specula work on the same principle: plates inserted on the incisor occlusal surfaces hold the mouth open by ratchets, screws, locking pins or friction clamps. There are three categories of full-mouth specula: 1) the lightweight, collapsible ratchet speculum (McPherson, Haussmann, and Series 2000); 2) the screw-type speculum (Gunther, Stubbs, and Butler); and 3) the oversized compound-action, hinged-type speculum (Conrad, McAllen, and AlumiSpec).

The McPherson or Haussmann types are the most widely used and most economical specula, and have been in use for over 100 years.⁵ Modern specula using ratchets and interchangeable incisor plates still employ this basic design. These specula come in a standard horse size, as well as in a smaller version for use in ponies and miniature horses. A McPherson speculum, with three or four teeth in the ratchet, is difficult to open to the widest setting. This problem has been overcome by using up to 33 teeth, as in the Series 2000 (2020) made by World Wide Equine (Fig. 16.12). Capps Manufacturing makes a larger speculum similar to the Series 2000, but uses a sliding lock rather than a small-teeth ratchet. This unit is infinitely adjustable (Fig. 16.13). All McPherson-type speculum incisor plates can be replaced with palate or bar plates, allowing use on parrot mouth horses, horses with no incisors, or horses with incisors too loose or damaged to support the incisor plates. Offset incisor plates are available for horses with an underbite or overbite. A 6.35-cm diameter plastic pipe (10.16 cm long) can be used to cover the incisor plates, allowing the speculum to be used as a gag in the interdental space, thus exposing the incisor teeth.

A single-threaded bolt opens the mouth with the Stubbs or Gunther screw-type specula. The Stubbs or Gunther specula are best suited for open-mouth radiographs or oral surgery when the horse is in lateral recumbency, because



Fig. 16.14 Gunther screw type speculum. This model (with no cheek plates) works well for taking open-mouth radiographs or working in the mouth of a recumbent, anesthetized horse.

there is no mechanism next to the cheek (Fig. 16.14). With the Stubbs speculum, a large threaded bolt easily opens the speculum, and the bolt can be positioned conveniently on either side of the mouth. This speculum uses heavy wire beside the cheeks with the bolt centered on the incisor plates by extension arms, and is moved side to side to gain access to each side of the mouth (Fig. 16.15).

The McAllen design uses a lever to open the speculum. The lightweight AlumiSpec sold by Veterinary Dental Products is based on the McAllen design but uses a heavy nylon tape and a pinch lock instead of a pin aligning in holes to hold



Fig. 16.15 Stubb's screw mechanism, full mouth speculum with elastic pole straps. This speculum is easy to open and has infinite adjustments. The central screw can be rotated from side to side giving good access to all areas of the mouth.



Fig. 16.16 The AlumiSpec, lightweight, leverage-type, full-mouth speculum has a nylon grip tape locking mechanism for easy opening and infinite adjustments.

it open (Fig. 16.16). Because of their large size and weight, the Conrad, Meister, and McAllen hinged-type specula can be dangerous in horses that are not adequately sedated and/or well restrained. Both the Conrad and the Meister specula are made from stainless steel and copy the brass McAllen design; however, all are out of production.

All specula can deliver serious injury if the horse swings its head unexpectedly. Everyone in the work area must be continuously aware of the horse's attitude. Owners or any other person not covered by the caregiver's liability insurance should be a safe distance away.

Illumination

Illumination is especially important for a complete oral examination and performance of corrective procedures with motorized instruments. Head-mounted lights are most useful for oral cavity illumination. Numerous types of head

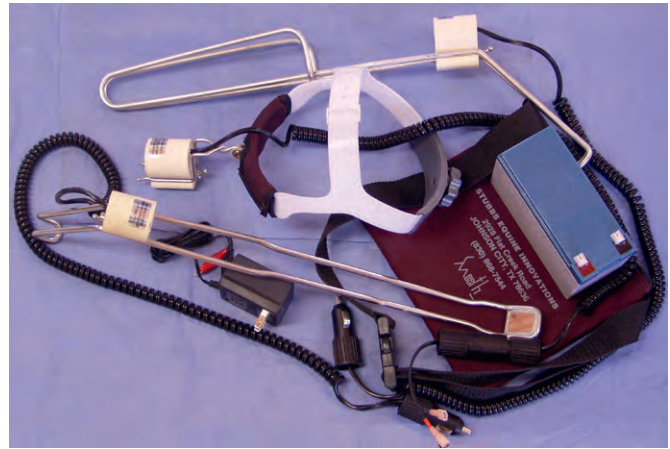


Fig. 16.17 Stubb's equine dental light. This bright, battery-powered unit attaches to a headband, dental basket type retractor, and/or a rigid shaft dental mirror.

lights are available; some have been adapted especially for equine dentistry, but many are intended for a variety of other activities.

Spelunking and camping head lights are convenient but limited in intensity and are mounted too far up on the forehead to position the light where it is needed. Several magnetized lights attach to the incisor plates of most specula and allow for continuous illumination of the mouth. Another nice feature of these lights is that they minimize the effects of the caregiver's head movement while keeping the light positioned on the patient's oral cavity. Stubb's Equine Innovations offers a multipurpose light that can be used as a head light and can also be used to illuminate the Stubb's Arcade Speculum or Stubb's Intraoral Mirror (Fig. 16.17). Hand-held flashlights or lamps mounted on the floor or ceiling can be used as well. All of these lights are not bright enough if the caregiver is working in bright sunlight or if very bright illumination is needed. When using a mirror, probes, periodontal instruments, or when extracting cheek teeth, a halogen light or its equivalent is recommended. All these lights attach to a head harness, but the light is so bright and coverage so broad that light position is not as critical.

Soft tissue retractors

At various points during the dental examination, the practitioner may find it helpful to have an assistant retract the tongue and/or cheeks of the patient. An abdominal retractor or a specially designed equine dental basket or cheek retractor may be used to provide more adequate oral visualization.

Mirrors

Using a mirror in conjunction with dental picks and/or probes is helpful in allowing the practitioner to identify abnormalities in the mouth. Mirror fogging can be a problem when working in the oral cavity, particularly in cold weather. Warming the mirror or using alcohol, or an antifog wipe or

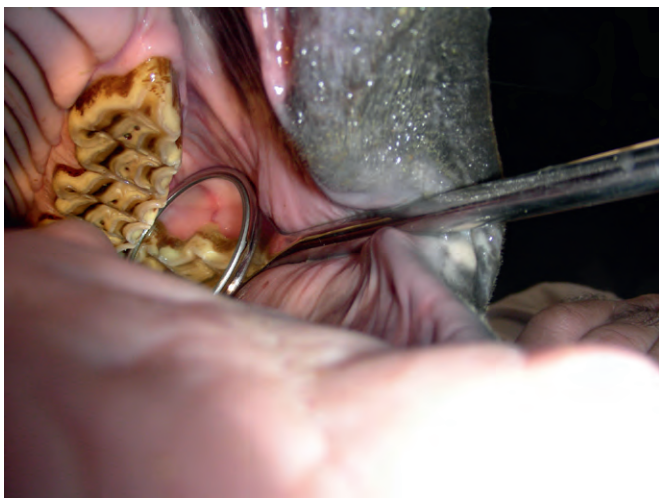


Fig. 16.18 A 4 cm, long-ridged shaft dental mirror with a 35° angled head. This instrument can also be used as a buccal and lingual retractor.

spray designed for reading glasses can be helpful in eliminating this problem. Most mirrors need to be set at a 35°–45° angle to their handles to allow adequate visualization around the cheek teeth. A long, ridged shaft allows the mirror to be used as a soft tissue retractor (Fig. 16.18).

Imaging

Once potential dental abnormalities are identified, imaging modalities, such as radiographs and ultrasound, may be used to gain more information about the problem at hand. A rigid endoscope, digital camera, and/or video recording equipment can be used to identify and record lesions and document the performance of various procedures⁶ (Fig. 16.19). This documentation is a useful record of care and can be used to educate clients and other veterinarians. (See Ch. 12.)

Dental floating equipment

Manual floats

Manual floats continue to be widely used in equine dentistry. The variety of blades, heads, shafts and handles currently available to practitioners is extremely useful in performing prophylactic procedures. The most durable and aggressive float blades are made from solid tungsten carbide.

For many years, float blades with tungsten carbide chips have been used as abrasives. The process for combining tungsten with carbon was discovered in the 1920s. Tungsten carbide is very hard, making it a better cutting agent than the previously used steel files. Carbide chips come in several sizes, with the small to medium grits being the most versatile. Solid carbide float blades, usually a combination of tungsten, carbon, and cobalt, remove tooth material much more easily than carbide grit. These blades are made from a powder that is compressed into the blade shape, and then sharpened. They are smoother because they shave off a layer of tooth. Fine to medium blades are better than coarse blades and are more resistant to chipping. Solid carbide



Fig. 16.19 Portable oral endoscopy equipment. This complete system can be used to visualize the oral cavity and document findings with still digital images or video recordings. System contents: 1) rigid (at least 40 cm long) laparoscope with a 35–90° wide angle lens; 2) 150 watt halogen light source and camera receiver unit; 3) single chip video camera with a focusing laparoscope adapter, and 200 cm long coaxial cable; 4) fiberoptic cable 200 cm long; 5) still digital image capture device; 6) digital video recorder, camera; and 7) flat LCD screen for viewing image.

blades produce less vibration than grit blades. Their use may allow the practitioner to decrease the amount of sedation required. These blades historically have been relatively expensive, but they are so effective and efficient that many practitioners now use them. Most blades originally consisted of a tungsten carbide rasp blade bonded to a plate of stainless steel, variably sized to fit the desired float head. More recently, tungsten blades have been directly bonded with adhesive or strong magnets to the float head or shaft, resulting in a slimmer float design. Most carbide blades cut in only one direction, so care must be taken to ensure that they are properly set on the float to cut either on the push or pull, depending on the desired use. For working on the 11s, blades should be set to cut on the pull, because if the blade slips off these teeth on the push, the blade will strike the caudal end of the mouth.

Tungsten carbide blades range in classification from ultrafine to coarse, with each manufacturer having individual scales of aggressiveness. The finer (less aggressive) blades stay sharp longer and can be resharpened more times than the coarser (more aggressive) blades. Most blade manufacturers offer an economical sharpening service to practitioners. In general, the fine and medium blades are best for general floating, while the coarse blades are reserved for reducing large overgrowths. Though these blades are sharp, the teeth of the blades are brittle, so one should handle them with care. Since different parts of the blade act as the cutting area when used in different handles, blades can be switched to different handles as they become dull in order to get additional use before they need to be resharpened. It is, however, important to recognize when a blade is completely spent and needs to be sharpened or replaced.

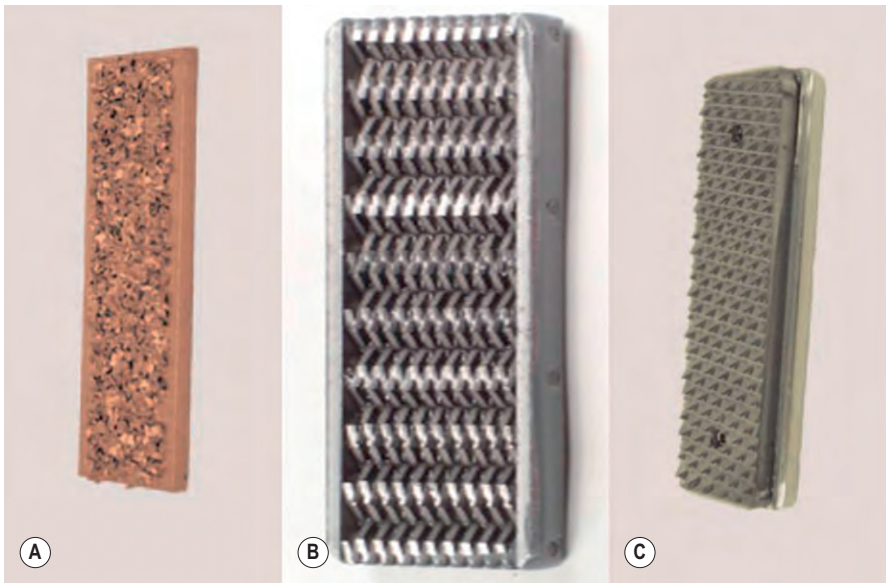


Fig. 16.20 Three types of manual interchangeable float blades: (A) medium grit carbide chip blade; (B) Jupiter speedy cut blade; (C) solid tungsten carbide blade with a stainless steel back.



Fig. 16.21 Solid tungsten carbide interchangeable float blades in several shapes ranging from fine to coarse cutting surfaces.

Solid tungsten carbide is preferred for blades because it reduces by one half, over the carbide grit blades, the average equilibration time. Other blade designs are available in addition to tungsten carbide, including carbide grit blades, steel file (Dick) blades and Jupiter Speedycut float blades (Fig. 16.20). Carbide grit blades come in various sizes of grits or coarseness and cut in both directions, i.e., on the push and the pull. The Dick blades have been discontinued by most companies because the steel blades are inferior to carbide products in durability. The Jupiter blades are made of either stainless steel or tungsten carbide and are also designed to cut in both directions.

The standard interchangeable float blade has square corners and is 7.62 cm long by 2.54 cm wide (Fig. 16.21). Changes in the size and shape of blades have recently been introduced by several manufacturers. Capps Manufacturing uses triangle-shaped solid carbide inserts. The inserts are placed in a triangular holder, and after tightening, form a solid cutting surface. The advantage with this type of blade is that singular inserts have three available cutting surfaces and individual inserts are replaceable. Kruuse Veterinary Supply makes a convex shaped blade that makes reducing tall teeth easier.

Manual dental floats are constructed in a variety of configurations. Float heads should be made to cover the sharp corners of the blade and fit the area of the mouth to be floated. Float head weight and thickness vary depending on intended use and operator preference. Float shafts may be round, three-quarter round or flat. Round shafts slide through the operator's fingers more easily than flat shafts. Flat shafts allow the operator to more accurately assess the blade's angulation in relation to the tooth being floated. Three-quarter round shafts combine the advantages of both the round and flat shafts. Float handles may be constructed of wood, plastic, metal, rubber or molded acrylic and can be padded or unpadded. They may be configured in either a pistol grip or a shaft grip and should be an appropriate size for the hand of the operator.

Hand floats come in a myriad of shapes and sizes (Fig. 16.22). Different shapes and lengths of floats are employed to reduce sharp enamel points on the various teeth, create bit seats, and reduce more major overgrowths (see Ch. 17). A minimal set of floats should consist of: a short, straight float; a long, straight float; an upper back molar (15° angle) float; and a premolar float (15° contra/oblique angle).

Practitioners may want to consider a variety of specialized floats for their dental equipment selection. A long offset float may be used to float the lower dental arcades. A float, consisting of a 22.86 to 38.1 cm shaft, offset head and short blade box, is used to create and/or 'polish' bit seats. Some manufacturers offer smaller floats made specifically for miniature horses, and extra-long handles can be purchased for use in large/draft horses. Carbide chip or diamond S-floats and steel files are often used to polish bit seats, smooth incisors, and reduce canines. A long, wide S-float, also called a table float, can be used to reduce sharp areas in horses with wave mouth or other types of uneven arcades (Fig. 16.23).

Float selection:

- Grips should fit, be nonslip, and feel comfortable when handling.



Fig. 16.22 A set of manual equine dental floats with stainless steel, flat shafts, and rounded neoprene handles. Both direct bonded and interchangeable solid tungsten carbide blades are used with this set.



Fig. 16.23 Table rasps with 40 cm long shafts, curved, carbide chip coated convex concave blades.

- Having some floats with a pistol grip, rather than an inline grip, reduces strain on the wrist that occurs when floats are held in the same position on every float.
- Smaller float blades (2.5 cm × 2.5 cm) work best in the caudal end of the arcades. Blades glued to the float are slim and best for 111 and 211 teeth.
- Long, straight floats may have the blade slightly elevated from the handle by the thickness of the blade or raised from the handle by an offset.
- Right angle offsets are difficult to use on the upper molar arcades and are generally used for premolar contouring.
- Flat-shafted handles, three-quarter round handles, and pistol grip handles immediately let the operator know the blade angle on the teeth.
- The blade should have blunt corners to prevent soft tissue injury.

Power instruments

Motorized equine dental instruments were first used in Germany in the 1930s.⁵ The use of power instruments in



Fig. 16.24 Sedated horse in stocks with head supported in a rigid halter, suspended from a rope with a quick release friction lock, attached to an overhead hook. A McPherson type speculum in place with a Powerlite attached to the upper incisor plate, illuminating the mouth. The battery operated Powerfloat is used to reduce dental elongations. The veterinarian wears examination gloves, goggles for eye protection, a dust filtering mask, and ear plugs.

equine dentistry has generated controversy, but when used correctly, they allow for precise corrective procedures with minimal soft-tissue trauma. Proper safety precautions for both the operator and the horse should be exercised (Fig. 16.24). Since more tooth can be removed with less physical exertion on the part of the operator, excessive crown removal and even pulpar exposure has occurred in some cases. Operators should be especially observant when these instruments are being used.⁷⁻¹⁰

Motorized floats come in three basic designs: 1) cable-operated, rotating burs in line with the float shaft (with or without an articulating head); 2) rotating discs turned 90° to the shaft; and 3) reciprocating floats. They can be electric, battery, or pneumatic powered. All AC-powered floats should always be on a stationary Ground Fault Circuit Interrupter or plugged into portable Ground Fault



Fig. 16.25 Guarded diamond dust equine dental burs used with a flexible cable motor. (A) Various inline guarded burr heads for reducing dental overgrowths. (B) Guarded diamond burs with quick release, medium length shafts. (C) Long shaft, diamond dust, guarded burs for reducing dental overgrowths in the caudal aspect of the equine oral cavity.

Interrupter to prevent electrical shock. A variable speed regulator with a handle trigger or foot pedal controller is helpful to prevent excessive crown reduction and minimize soft tissue damage.

Rotary cable floats are quite effective in removing sharp enamel points and reducing overgrowths. Some motorized equipment still uses Dremel motors. However, the Dremel, a type of rotary cable grinder, should not be used for equine dental work due to the electric shock hazard of working in a moist environment (i.e., the mouth). (Note: Dremel does not recommend nor offer warranty for the use of any of their tools in equine dentistry.¹) Several manufacturers have various lengths of guards and extensions to facilitate good control and minimize soft-tissue damage in all areas of the oral cavity. Some instruments have built-in vacuum systems that reduce the operator's exposure to dental dust and improve visibility. Other units may have irrigation systems that reduce dust and decrease the risk of thermal damage to the teeth. Some units contain both a light source and an irrigation system. A built-in clutch makes these units safer for the horse, and decreases the incidence of cable breakage. Solid tungsten, rotary-powered burs are available in a variety of cutting teeth and degrees of coarseness. A fine, cross-cut burr does not tend to jump off the tooth during rasping, as is often the case with spiral-cut burs. Burs or grinding drums, coated with fine carbide grit or diamond chips, are available in a variety of shapes (Fig. 16.25).

Disk burr instruments have become increasingly popular as they are less apt than rotary burs to damage the soft tissues inside the oral cavity. Additionally, it appears to be easier for an operator to master the use of disk type motorized instruments. These instruments are manufactured with various lengths of shafts and run from fixed electric or battery-powered drills or flexible shaft motors (Fig. 16.26). Instrument head design and thickness vary between manufacturers. The cutting surface of the disk is made from solid tungsten carbide, fine carbide grit, or diamond dust. Examples of these instruments include the Eisenhut Swissfloat, the PowerFloat, and the Horsepower hand piece. The Eisenhut consists of a hand-held electric drill motor with a 4-cm, circular, stainless steel, carbide or diamond disk that rotates horizontally at the end of a shaft that comes in three different lengths up to 65 cm (Fig. 16.27). This instrument is useful in reducing caudal mandibular overgrowths even in large horses due in large part to the length of its shaft.¹⁰ The PowerFloat

comprises a 2.5 cm tungsten carbide chip disk that rotates horizontally at the end of a 45-cm long shaft. This low-profile power instrument can be used for numerous corrective procedures, including caudal 11 overgrowths in small ponies. The Horsepower hand piece is modified to fit the Dremel or Fordon motor with a flexible shaft drive.

Many reciprocating floats are electric or battery-powered and are modifications of woodwork power saws, varying in stroke length and strokes per minute. Several manufacturers (Stubbs, Olsen and Silk, and Carbide products) make pneumatic reciprocating floats that make short strokes at high speed. Some operators have developed hand problems caused by the vibration of pneumatic floats, and it is suggested that antivibration gloves be worn when performing corrective procedures with these floats. Most of these instruments have a thin carbide blade bonded to the shaft, similar to those used on some manual floats (Fig. 16.28). Long-stroke reciprocating floats are also available and are used to reduce excess crowns and sharp enamel points. Long-stroke reciprocating floats should not be used on the third molars due to risk of iatrogenic mandibular or soft-tissue trauma. A polymer lubricant used with reciprocating pneumatic instruments reduces heat produced by friction and airborne dust.

Factors to consider with motorized equipment:

- If used improperly, all motorized floats can overheat teeth to the point of pulp damage. Lower speeds in the 2000 to 3000 r.p.m. range are preferred because higher speed rotation produces heat faster. (Note: use light pressure on the float, keep it moving.)
- Irrigation eliminates thermal damage, but care has to be taken to prevent electric shock. Irrigation also reduces dust, and suction helps remove both dust and excess water. (Note: irrigation fluid can freeze in colder climates.)
- To prevent inhalation of dental dust, a mask should be worn when using the visual method for floating or when incisors are being leveled.
- Cable grinders should have a clutch to prevent soft tissue damage in case a burr contacts and pulls in either cheek or tongue. A clutch also prevents cable breakage if the horse bites down on the burr.
- Disk tools should have a clutch to prevent motor damage if the horse bites the disk.



Fig. 16.26 (A) Battery operated Powerfloat with quick release, interchangeable shafts and grinding heads. (B) Disk carbide grit burr with 45° beveled head. This burr is used to reduce sharp enamel points and prominent cingula from the buccal aspect of the upper cheek teeth and lingual edges of the lowers. (C) Carbide diastema burs that attach to the right angle head of the Powerfloat. These burs are used for opening a space between teeth with valve diastema.

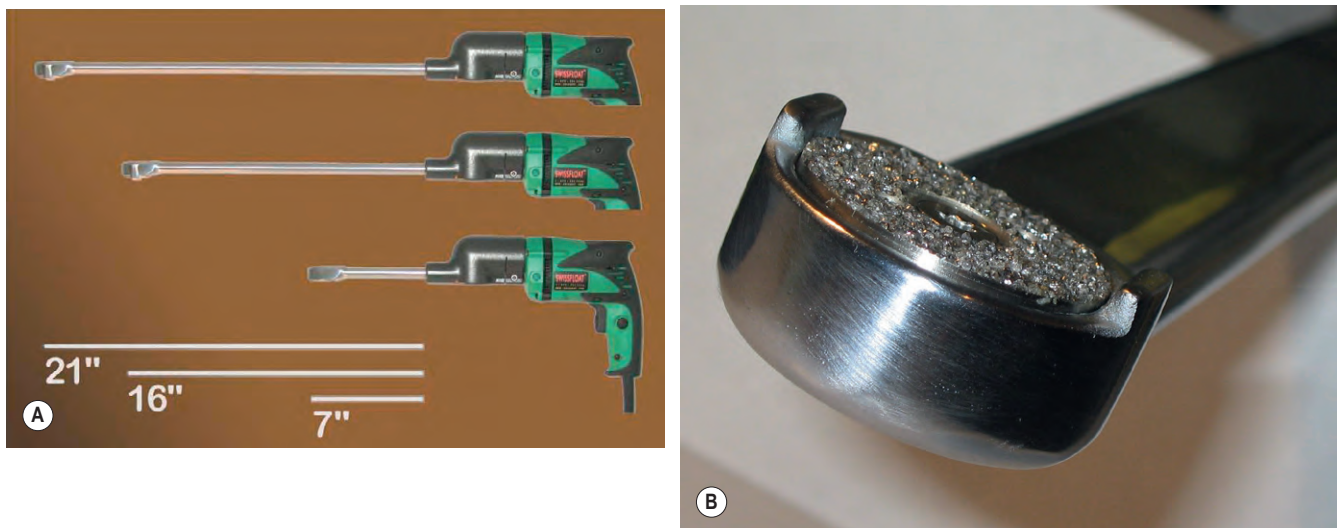


Fig. 16.27 (A) The Swissfloat with right angle disk burr comes with three different length shafts. (B) Close-up of a Swissfloat diamond disk float head.

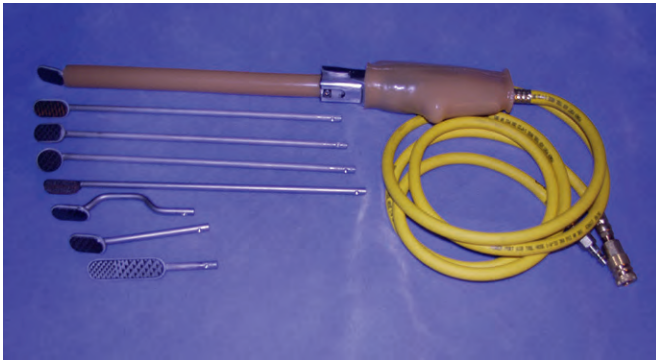


Fig. 16.28 Stubbs pneumatic powered oscillating floats have a short stroke length with variable speeds. This type of instrument comes with quick release, interchangeable floats and a wide variety of attachments.



Fig. 16.29 Reynolds type upper and lower cap forceps for removal of retained deciduous premolars. The handle length, shape, and jaw sizes are designed to firmly grip the appropriate tooth for removal.

Safety of the operator, the assistant(s), and the equine patient during motorized instrument use can be optimized in several ways. Protective eyewear and an air filter mask reduce the chance of debris and tooth dust getting in the eyes and/or being inhaled. Ear protection should be considered if loud electric motors are used close to the operator's head or noisy air compressors are in operation nearby.

Special equine dental instruments

Deciduous tooth instruments

Various forceps, elevators, and dental picks are available to remove retained, displaced, or broken deciduous cheek tooth remnants (caps) (Fig. 16.29). A set of deciduous tooth instruments should consist of short-handled molar forceps and dental elevators or a modified screwdriver (see Chapters 17 and 20).

Picks, probes, and periodontal systems

Ancillary equipment for a thorough oral examination includes picks and probes for identifying and measuring periodontal pocketing, open pulps, infundibula and fractures. Scalers and gingival elevators can be used to remove calculus from cheek teeth, clean out perio pockets, or elevate gingiva prior to extractions (Fig. 16.30). These are in addition to the standard picks used to loosen tooth fragments.

Dental picks are used to clear debris from and to probe diastemata and crown defects. They are also helpful in

extracting tooth and root fragments in aged horses. Some practitioners have adapted a wire coat hanger as a useful and inexpensive dental pick or probe. Additionally, an insemination pipette, curved by being held over a flame just long enough to make the plastic bendable, is a useful dental probe and flushing device. Special calibrated human or small animal periodontal probes can be modified on a long handle and used to explore and measure periodontal pockets. Needle probes should be used to access the occlusal surface for patent pulp horns. Large probes are used to evaluate gingival attachment and infundibula. High pressure oral irrigation units can be used to flush food and debris from diastemata and periodontal pockets (Fig. 16.31). Human periodontal systems modified with long handpieces, using compressed nitrogen or air to propel water with sodium bicarbonate, are available for cleaning periodontal pockets. These units also have high-speed drills for tooth restoration (Fig. 16.32).

Canine tooth instruments

Instruments have been developed to reduce the crown of sharp canine teeth as well as to scale and buff older canine teeth with tartar accumulation. A full set of canine tooth instruments consists of: 1) a straight-handled, fine-grit, tungsten carbide dental rasp; 2) a small dental scaler 3) a wire-bristle toothbrush or nylon-bristle nail brush; and 3) Oral Cleansing Gel (Addison Biological Laboratory, Fayette, MS). Nippers and cutters should not be used on canine teeth because these instruments offer minimal to no control during tooth fracturing. Opening the pulp or dentinal tubules can lead to pulpitis and tooth death years after the reduction. To avoid over-reduction of the canines, small files or diamond disc grinders (at low speed) should be used only for smoothening or to blunt the top of the canine.

Wolf tooth instruments

The length and style of wolf tooth elevators depends on a practitioner's preference (Fig. 16.33). To avoid possible root fracture, one-half or three-quarter circle elevators are preferred because the palatal, rostral and buccal sides can be elevated independent of the caudal side. This allows the entire tooth space to move when elevated on the caudal side. When the elevator is in position, a rubber mallet is used to lightly tap the elevator to loosen the tooth on three sides. Once loosened, the elevator is inserted on the caudal side of the tooth for the final elevation. The rubber mallet absorbs much of the concussion, preventing head motion that can occur in a sedated horse with an anesthetized tooth. (See Chs 17 and 20.)

Molar cutters and chippers

The use of percussion instruments to reduce overgrowths has been practiced since the early 1800s. Yet, with the advent of motorized equipment, the use of molar cutters and chippers has declined. These tools are used to produce a controlled fracture of a tooth or portion of a tooth. Unfortunately, over the years, there was very little control displayed, and since the general recommendation is to avoid tooth reduction greater than 3–5 mm, molar cutters have just one indication – to

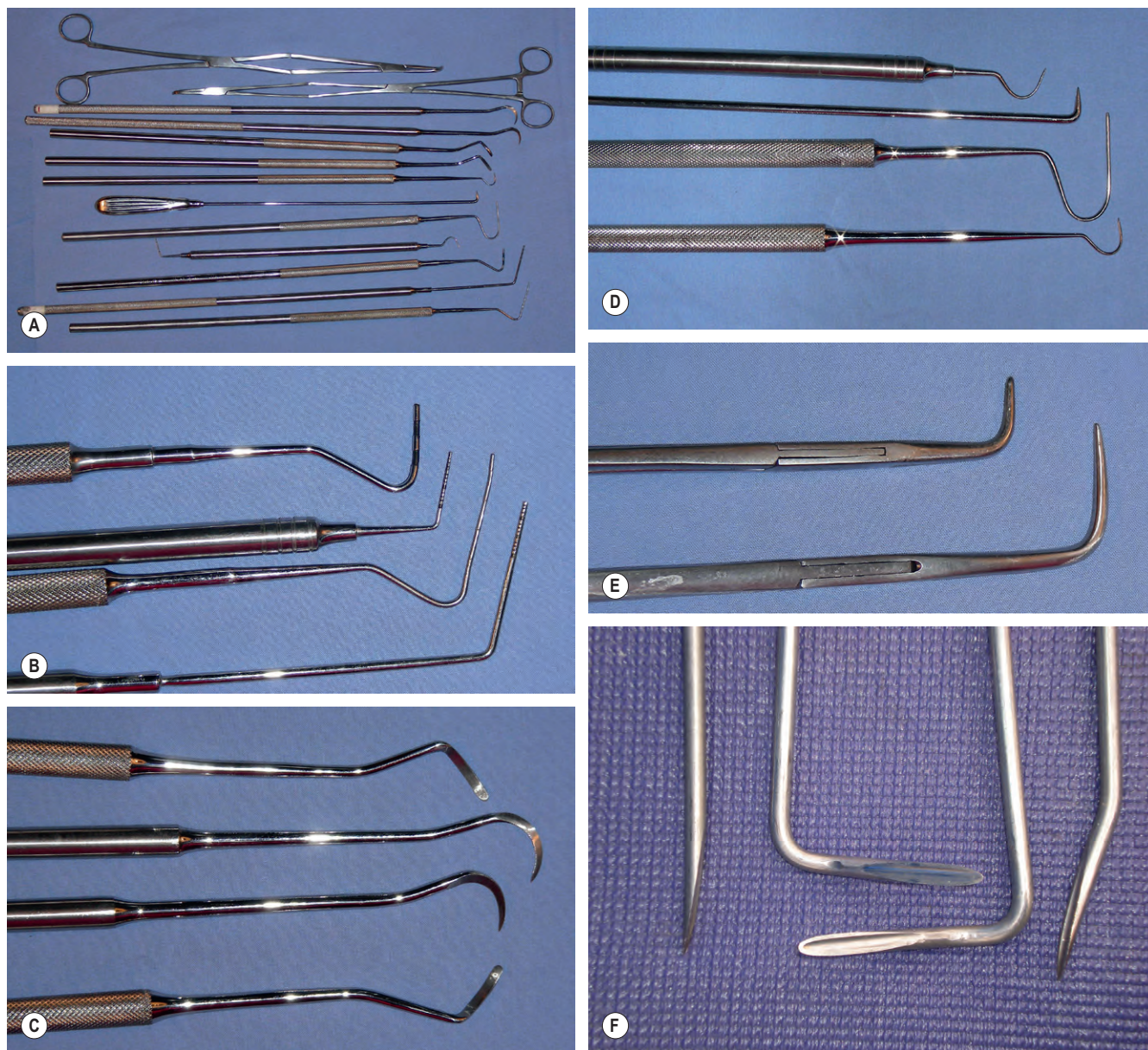


Fig. 16.30 (A) Set of long shaft equine dental picks, probes, scales, and periodontal forceps. (B) Calibrated periodontal probes. (C) Dental scalars. (D) Dental picks. (E) Periodontal forceps. (F) Heavy gauge dental picks.

shorten large tooth overgrowths in geriatric horses (e.g., a long caudal hook that is too long to apply a motorized float).

Molar cutters come in three sizes (A, B, and C head cutters) depending on the space between the jaws, which is 0.635, 0.952, and 1.27 cm, respectively. Cutters are sized so that when applied to a tooth or part of a tooth, the jaws are parallel.

Chisels and mallets, or chisels with sliding captive bolt hammers, have also been used to reduce enamel points, as well as rostral and caudal hooks. The Equi-Chip guarded chisel with a sliding hammer is a refinement of earlier devices. This instrument is no longer widely used since power tools have proven to be more efficient, precise, and safe in removing these types of overgrowths.

Dental extraction equipment

Removal of cheek teeth, wolf teeth, canines and incisors requires special equipment and supplies. Special operating room support is required in certain circumstances. Equipment and techniques for tooth removal are outlined in Chapter 20.

Periodontic, endodontic, and dental restorative materials

Areas of growing interest in equine dentistry include periodontal disease and infundibular decay.⁶ Specialized equipment, instruments, and medication are available to treat equine periodontal disease. Pacific Equine Dental Institute,

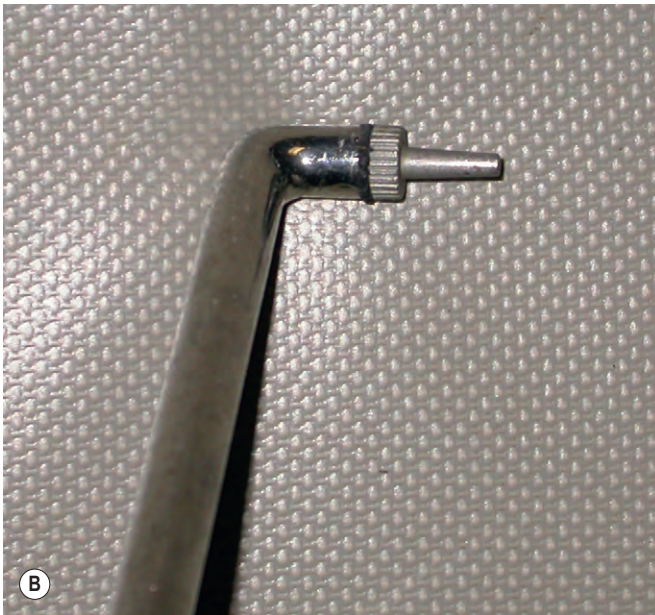


Fig. 16.31 (A) A high pressure dental irrigation unit made from a 4 L garden sprayer with a battery-powered bilge pump that delivers 65 p.s.i. (B) The right angle nozzle can reach between cheek teeth to clean periodontal pockets.

Inc. has adapted and modified human and small animal dental equipment for use in the equine patient. The Equine Dental System (Pacific Equine Dental Institute, Inc., El Dorado Hill, CA) is a self-contained, high-pressure (up to 200 p.s.i.) water-delivery spray unit that can be used to evacuate deep periodontal pockets. Additionally, this system contains a Prophy Air Abrasion Unit and a baking soda/chlorhexidine delivery system to clean out periodontal pockets and areas of infundibular decay. With this system, the equine practitioner can now provide the same level of periodontal care that is provided in human dentistry.^{11,12}

As in human dentistry, endodontics, orthodontics, and crown restorative techniques are now being utilized in equine dentistry. The equipment and materials needed for such detailed techniques are outlined in Chapters 21 and 22.



Fig. 16.32 Portable equine dental system with elongated hand pieces. This system is powered by compressed air. The unit contains an air abrasion unit as well as a low-speed and high-speed dental drill, water irrigation, and suction.



Fig. 16.33 A complete set of wolf tooth instruments including forceps, elevator, and Burgess-type extractor.

Conclusion

The quality and variety of equine dental instrumentation and instruction have improved greatly in just the last 5

years. New information and techniques emerge regularly, and equine practitioners should avail themselves of these improvements to remain current in the most recent developments. Many dental vendors and manufacturers can provide the equine practitioner with high quality instruments and supplies (see Appendix for supplier information).

Acknowledgments

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References

1. Allen T, Johnson T, Miller RO. Safety issues and restraint procedures. In: Allen T, ed. *Manual of equine dentistry*. Mosby, St Louis, 2003, pp 43–48
2. Scrutchfield, WL, Easley, KJ, Morton K. Equine dental equipment, supplies and instrumentation. In: Baker GJ, Easley J, eds. *Equine dentistry*, 2nd edn. Elsevier, 2005, ch. 15, pp 205–292
3. Schultze W, Allen T, Mitz C, Johnson T. Dental tools and equipment. In: Allen T, ed. *Manual of equine dentistry*. Mosby, St Louis, 2003, pp 17–41
4. Pence P. Dental equipment in equine dentistry. In: Pence P, ed. *Equine dentistry: a practical guide*. Lippincott, Williams and Wilkins, Philadelphia, 2002, pp 25–52
5. Fahrenkrug P. The history and future of equine dental care in: *Proceedings North American Veterinary Conference*, Orlando, 2005, pp 151–154
6. Easley J. How to perform and interpret an endoscopic examination of the equine oral cavity. *Am Assoc Eq Pract Proceedings* 2008; (54): 383–385
7. Greene S. Equine dental advances. *Equine Practice* 2001; 17(2): 319–334
8. Dacre KJP, Dacre IT, Dixon PM. Motorized equine dental equipment. *Eq Vet Edu* 2002; 4(5): 337–340
9. Baker GJ, Allen ML. The use of power equipment in equine dentistry. In: *Proceedings of 48th Annual Convention of American Association of Equine Practitioners*, 2002, pp 438–441
10. Kempson SA, Davidson ME, Dacre IT. The effect of three types of rasps on the occlusal surface of equine cheek teeth: a scanning electron study. *J Veterinary Dent* 2003; 19–27
11. Pence P, Basile T. Dental infection in equine dentistry. In: Pence P, ed. *Equine dentistry: a practical guide*. Lippincott, Williams and Wilkins, Philadelphia, 2002, pp 209–229
12. Allen T. Other procedures. In: Allen T, ed. *Manual of equine dentistry*. Mosby, St Louis, 2003, pp 157–173

Corrective dental procedures

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Introduction

Corrective dental procedures in the form of floating or reduction of sharp enamel points and tall tooth crowns have been performed on equine patients for hundreds of years. These procedures performed on a regular basis have traditionally been part of a horse health care program with very little scientific evidence to support this practice. Corrective floating procedures are often performed to: 1) relieve discomfort associated with oral soft tissue injuries caused by sharp enamel points; 2) reduce dental elongations, which place stress on affected teeth and jaws; 3) improve mastication and digestion of feedstuffs; 4) alleviate stresses on abnormally worn teeth; and 5) prevent discomfort and improve performance in the horse wearing a bit and bridle.^{1–10} Most dental corrective procedures concentrate on reduction of abnormal dental elongations. The true pathology often involves the tooth opposite or out of occlusion with the elongated dental area. Failure to evaluate and properly address the pathological process may lead to recurrence of the elongations and a temporary or unsatisfactory result for the patient. A careful and complete oral examination is critical in the diagnosis of dental pathology and the planning of dental corrective procedures. A more scientific approach to equine dentistry has changed the way that many cases are managed. The practitioner should strive to do no harm to the horse or its teeth. The utilization of a complete set of good quality hand floats or power equine dental equipment allows dental corrective procedures to be performed with precision in an efficient manner (see Ch. 16).

There are four distinct levels of equine dental care. Historically, the first level of dentistry has been labeled dental prophylaxis or ‘floating teeth.’ It involves an oral examination and routine dental maintenance procedures, such as reduction of sharp enamel points, and reduction of small crown projections (hooks, beaks, small waves, and transverse ridges). The second level of dentistry is often referred to as performance dentistry. This includes dental prophylaxis and additional procedures developed in the hope of improving the horse’s comfort in accommodating the bit or other equipment (tongue-tie, hackamore, nose band, or

martingale) and allowing free rostrocaudal mobility of the mandible. Such additional procedures may include rounding off the rostral and buccal edges of the O6s (creating bit seats), the removal of loose deciduous teeth, and the extraction of wolf teeth. Corrective dentistry or dental equilibration describes the third level of equine dental care and involves procedures devised to reduce dental crown elongations (odontoplasty) and treat associated pathologies. Dental overgrowths may involve a portion of a tooth (hooks, abnormal transverse ridges), the entire tooth (step, ramp), several teeth (wave), or the entire arcade (shear mouth). Dental elongations can place abnormal stress on the affected tooth. These stress forces can cause the teeth to shift and ultimately lead to rostral or caudal displacement, linguoversion, or buccoversion. The resulting diastema caused from tooth displacement is a leading cause of periodontal disease. This high level of dental care usually requires a more thorough examination and at times ancillary diagnostics and imaging techniques to properly diagnose the problems and develop a precise plan for correction. Oral and dental surgery, periodontics, orthodontics and endodontics, the fourth level of equine dentistry, will be covered elsewhere in this text.

It is not always possible to assign an equine patient to a level of dental care prior to making clinical contact. A dental history and physical examination along with a complete oral/dental examination usually establish the level of care the horse requires. Occasionally, the veterinarian may be involved in what appears to be a routine prophylaxis when a tall, decayed, loose, or broken tooth is encountered. This may move the horse into a higher level of care. Horses requiring special diagnostic and therapeutic oral procedures may require referral to veterinarians with the equipment and expertise to properly diagnose and treat such problems. Taking a moment to educate trainers and owners about the value of a thorough dental examination, types of pathology, and indicated dental corrective procedures is time well spent. Dental forms or charts should be used to record abnormalities, corrective procedures performed, and any planned treatment. Dental forms also help in itemizing the bill and provide an estimate of professional fees before procedures are performed (see Ch. 12).



Fig. 17.1 Performing dentistry by feel. The horse is restrained with its head and mouth at chest level to the veterinarian. This method allows the practitioner to remain standing with correct posture for dental work.

Two approaches to performing dental corrective procedures have become standard over the past few years. Both involve examination and dental corrections carried out in a standing, sedated equine patient. In rare cases, general anesthesia may be required to thoroughly examine and treat dental problems. The less involved type of standing restraint has been described as ‘performing dentistry by feel.’ This type of dentistry is performed with the horse’s head at the level of the operator’s waist or chest (Fig. 17.1). This requires minimal sedation and works well for most horses with relatively normal occlusions that need only minimal routine dental corrective procedures. The horse’s head can be periodically elevated, and the oral cavity visually evaluated during the procedure.^{11–14} The second method commonly employed is ‘visual dentistry.’¹⁵ Working in the horse’s mouth visually requires the patient to be well restrained and more heavily sedated (Fig. 17.2). The animal’s head must be elevated and supported at a height that allows visualization of the mouth while the veterinarian maintains a comfortable ergonomic body position.¹⁶ Visual dentistry allows for a more thorough dental examination and precise correction of dental abnormalities. Both methods have their place in practice, but visual dentistry has many advantages over dentistry by feel, especially in horses with dental pathology or severe wear abnormalities. Working with dental instruments, including power equipment, requires strength, dexterity, and mastery of technique. The visual method allows better access to the mouth and lowers the learning curve on the use of equipment.

Dental corrective procedures, such as floating teeth, were once considered fairly innocuous. With the development of better quality and more efficient equipment to instrument the mouth and reduce dental crowns, dental correction can be overdone and have severe detrimental effects on the patient. Rasping teeth has been shown to amputate odontoblast processes, leave deep grooves in the surface of the dentin, and/or chip the enamel surface and peripheral cement. Modern motorized dental tools remove greater amounts of dental tissue, thereby increasing the risk of



Fig. 17.2 Performing visual dentistry. The horse is restrained with its head elevated, and the veterinarian is working while seated in front of the horse.

damage to pulp horns from overheating or direct exposure. It has recently been speculated that horses may suffer dental pain after corrective procedures.¹⁷ A fine-toothed burr or dental rasp used with light intermittent cutting strokes causes less damage in reduction. An efficient water cooling system and frequently cleaning the burrs may reduce the chance of thermal injury to the dentin and pulp.^{18,19}

This chapter is divided into five sections: 1) dental prophylaxis; 2) performance dentistry; 3) special concerns in treatment of miniature horses and draft breeds; 4) correction of cheek teeth and incisor overgrowths and associated pathology; 5) complications of dental corrective procedures. The dental equipment and instruments needed to carry out corrective procedures have been covered previously in Chapter 16.

Dental prophylaxis

In veterinary medicine the concept of prophylaxis, i.e., the ability to use a practice that prevents the development of subsequent serious disease, is the foundation of any health maintenance program. Dental prophylaxis, the examination of the oral cavity, and the use of corrective procedures to arrest disease processes before clinical signs are seen, have been reaffirmed as important parts of a patient’s health care program. Historically, ‘floating’ was a term that originated in the masonry and/or carpentry professions to describe leveling or smoothing out of plaster. In equine veterinary practice, floating involves the use of files, burrs, or chisels to remove the enamel points from the buccal aspects of the upper and lingual edges of the lower cheek teeth. Reducing and smoothing these sharp elongations make these areas that contact soft tissue less irritating, thus providing more comfortable mastication and biting for the horse.^{20–25} Floating may be the first dental procedure performed and can make the mouth more comfortable when using a full-mouth speculum. Or, it may be preceded by cutting, grinding, or

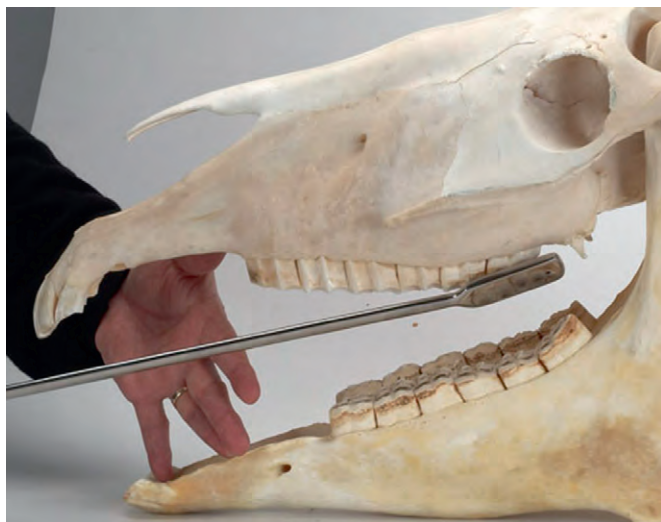


Fig. 17.3 Proper positioning of the back molar float with a slim 15° upper obtuse head. The carbide blade should always be set to cut on the pull stroke when using this float in the back of the mouth.

extracting teeth to provide a dental arcade that can be properly rasped. Hand floating by feel with minimal sedation will be described in detail. However, many practitioners use power tools in routine floating. Since each type of equipment requires varied techniques, it is recommended that one works closely with practitioners who have experience with the specific tools being used. Manufacturer recommendations on the use of particular power tools should be followed very closely.

Equine dental floating should be approached in a sequential fashion. A full set of floating instruments is needed to reach the various areas of the mouth. The upper buccal aspect of the central four cheek teeth is the easiest point of the arcades to float. The most appropriate tool to reach this area is a straight head float. The practitioner can introduce the float to the horse by allowing the animal to view, sniff, and feel the float's action on the outside of the cheek before inserting the instrument into the mouth. The initial strokes should be light and short, progressing along the length of the dental arcade. As the horse becomes more receptive to the tool, the stroke can be lengthened and more pressure applied to the head of the float. The position of the float head should be at a 45° angle to the buccal cusps. Hand position, which influences float head position, should be adjusted according to feel and sound. The high-pitched rough sound of sharp enamel points being rasped softens as floating continues. The 45° angulation of the float head should not be rigidly maintained, or two sharp angles could be left on the buccal aspect of the tooth. The float should be rotated slightly along the longitudinal plane to round the buccal tooth edges and reduce prominent singulare. This procedure should be performed on both upper dental arcades before proceeding to the next area.

The upper caudal molars (110, 111, 210, 211) should be floated next using a long-shafted straight float with an upward tilted or obtuse 10–15° head (back molar float; Fig. 17.3). The instrument is placed in the buccal space and eased to the back of the mouth. With short strokes on the pull, the float head is pressed against the buccal aspect of the last two



Fig. 17.4 A short-shafted float with a 20° downward obtuse head. This area of the dental arcade can be more easily floated without the speculum in place.



Fig. 17.5 A straight long-shafted float positioned for removing sharp enamel points from the lower arcades.

molars. The final area to be floated on the upper arcade involves the second and third upper premolars. The instrument of choice to use on these teeth is a short-shafted upper premolar float with a 20° angled head or a 9-inch offset head float (Fig. 17.4). The float is worked back into the mouth along the buccal aspect of premolars 2 and 3. Horses with 06 hooks, or performance horses that are bitted, require special considerations, and these are addressed later in this chapter.

A 15–17-inch long straight float with a 3-inch head or a carbide chip table rasp can be used to float the lower arcade (Fig. 17.5). This instrument is introduced along the lingual aspect of the lower molar table with a mouth speculum in



Fig. 17.6 Horse restrained with a metal frame dental halter similar to a martingale, to float the lower arcades by feel.

place. Horses have a tendency to raise their heads when the lower arcades are floated. A dental halter used as a martingale is helpful in holding the head in proper position (Fig. 17.6). Tongue retraction should never be used as a method of restraint when floating. The hyoid apparatus can be fractured, with serious complications ensuing. A back molar float can then be used to round the caudal edges of the last lower molar. Horses with 06 hooks or performance horses that are bitted require special considerations, and these are addressed later in this chapter.

With a full mouth speculum in place, the entire upper and lower molar arcades should be digitally and visually inspected. Finally, any areas of asymmetry or overlooked sharp points can be addressed. The speculum is removed, and lateral jaw excursion to molar contact (EMC) re-evaluated for balance, symmetry, and incisor contact. Depending on the horse's age and use, other corrective procedures may need to be considered (see DVD).

Performance horse dentistry

In addition to regular dental prophylaxis, several areas of the dental arcade are of particular interest to veterinarians working with performance horses. Since the horse was first domesticated, reins and bits have been used to send cues from the rider to his mount. Today's performance horses are involved in a wide variety of disciplines. In most endeavors, the equine athlete wears a bridle and bit for control. Oral and dental problems often lead to bad habits and vices, such as resisting the bridle, poll sensitivity, and head shaking. Over 100 years ago, Merillat, in his thesis on horse dentition, summarized the importance of dental care in the performance horse:

In drivers, runners, and saddle horses enamel points are the greatest sources of annoyance. The expert reinsmen will properly recognize their presence by the horse's behavior in harness. Lugging, side reining, ptyalism, and tenderness about the seat of the bit are manifestations of pain from the bridle and are symptoms of these points. The aim in dressing the teeth of a horse should be to simply blunt the enamel points along the course of the arcades and to round up the first superior and inferior molars as smooth as an ivory ball.²⁶

A recent Swedish study has shown an increased incidence of oral ulcerations in horses ridden with bit and bridle than in horses not ridden.² Floating the teeth to remove sharp points has been shown in a clinical study to have a positive effect on the trainer's perception of the horse's response to the bit.²⁷ The effect is enhanced by rounding the premolars in what has been referred to as 'bit seating.' A randomized, controlled, blinded trial demonstrated that dental floating increased the rostrocaudal mobility of the mandible when flexing and extending the head, which may be beneficial to horses working with a more vertical head carriage.⁹ Studies on the position of the bit in the horse's mouth and surgical correction of bit-induced bar injuries have shed new light on biting problems.^{28,29} Performance horse dentistry entails: 1) normal dental prophylaxis; 2) slightly rounding the 06s (creating bit seats); 3) care or removal of wolf teeth; 4) deciduous teeth management; and 5) evaluating canine teeth. Types of bits and contact points on the horse are reviewed in Chapter 3.

When evaluating performance horses, the veterinarian must keep in mind that subtle points and hooks or a difficult-to-detect loose or painful tooth may cause great personality and performance changes in the elite equine athlete.³⁰ An important consideration when working on the performance horse's mouth is to remove any sharp or protruding edges from teeth that could make contact with the tender soft tissues of the mouth. A good test for detection of sharp points is to position the fingers just in front of the masseter muscles on both sides of the cheeks at the level of the upper molar arcade. Place firm pressure on the cheeks, pressing them into the teeth and moving the fingers forward. Press the commissures of the lips back against the rostral edges of premolar 2. If the horse flinches or tosses its head, the animal is feeling pain from sharp enamel points.³¹

A regular dental floating usually resolves most problems. The rostral edges of the upper and lower second premolars (106, 206, 306, 406) should be carefully rounded to provide a smooth surface against which the cheeks can rest when bit pressure is placed on them. This procedure, termed 'creating bit seats' is performed in an attempt to make the performance horse as comfortable as possible for a reasonable period of time as the bit pulls or pushes soft tissue against the premolar teeth. These teeth should be shaped like the end of an index finger. There are differences of opinion about the need for creating bit seats, the degree to which the teeth should be beveled, and the smoothness required.^{21,25,32,33}

To shape the upper teeth (106, 206), several cuts are made. The first is the outside (buccal) cut. The instrument of choice for this cut is a 9-inch float with an offset head. When



Fig. 17.7 A short-shaft float with offset head is used to create the 'bit seat'. This float can be easily used over the incisor plates of a McPherson-type full mouth speculum.

floating begins, the handle is held on the ipsilateral side of the tooth and is subsequently worked across to the opposite or contralateral side of the face between the open incisors (Fig. 17.7). This rolls the head of the float from the buccal aspect of the second premolar to its rostral buccal aspect and then rostral aspect. This cut is followed by an inside cut to the same tooth with the same float. The float is positioned at a 30–45° angle to the lingual surface. Strokes should be made on the lingual edge of the tooth in order to round the rostral aspect. The objectives of the inside and outside cuts are to produce a narrow edge shaped much like a boat hull which can be blunted with a crosscut. The float is introduced from the contralateral side, placed at a 45° angle, to the point, and short vibrating strokes are made. Two fingers may be placed on the outside of the cheeks to serve as guides (similar to how a person holds a pool cue). To observe float placement, the commissure of the lips should be retracted. The last cut made is the fan cut. The float head is placed at a 30–45° angle to the rostral point of premolar 2, and using a fanning action, short sequential strokes are made. Strokes are initially made on the buccal aspect of premolar 2. A half-circle is rolled or cut starting buccally and is continued around the rostral and lingual surfaces of the tooth. This blends the three prior cuts. The last cut is easier to perform using a full mouth speculum. The float is inserted into the mouth over the speculum incisor plate.

The final step in performance horse floating requires floating the lower first cheek teeth and shaping the lower bit seats. These lower teeth, like the upper second premolars, need to be slightly rounded and shaped symmetrically, relative to one another. The bit seats are formed with the same cuts used on the upper arcade. Ideally, the bit should lie on the tongue and not against these teeth. The bit seats and the rest of the arcade should be evaluated for symmetry and balance. Sharp buccal points on premolars 3 and 4 should be reduced as they can cause nose band pain. Severe tooth damage can occur from over-reduction of the crown and lead to pulp horn damage. Finally, lateral jaw excursion should be evaluated. If indicated, the incisor teeth should be addressed appropriately, as is discussed later in this chapter.

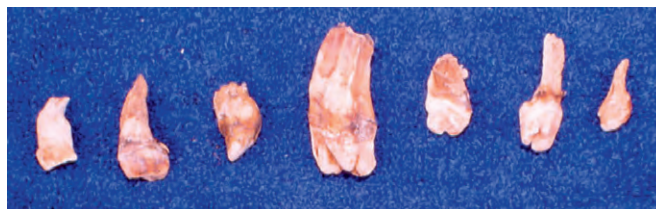


Fig. 17.8 Wolf teeth come in a wide variety of sizes and shapes.



Fig. 17.9 Thirty-month-old horse with wolf teeth positioned close to the 106 cap and 1 cm rostral to the 206 cap.

'Wolf tooth' is the common term used to describe the first premolar.³⁴ The number, position, size, and shape of these teeth are quite variable. The appearance of the exposed crown is not necessarily a reflection of the size or shape of the root (Fig. 17.8). Forty to ninety per cent of domestic horses erupt at least one upper wolf tooth. Lower first premolars are uncommon.³⁵ Wolf teeth usually erupt at 6–18 months of age but this too may be quite variable. In some 2–3-year-old horses, wolf teeth are shed concurrently with the second deciduous premolar caps. The larger erupting permanent second premolar tooth often causes root resorption of a wolf tooth that is positioned close to the deciduous second premolar. This probably accounts for the high percentage (80–90%) of horses under 2 years old with wolf teeth and the lower percentage (15–25%) found in adults, even in groups of horses having had no previous dental work. Wolf teeth are usually positioned just rostral to the upper PM2s, but they can be positioned on the buccal side of the first cheek teeth or up to 1 cm rostrally to these teeth (Fig. 17.9). Double wolf teeth have been seen, as well as teeth displaced into the interdental space. Unerupted wolf teeth, referred to as 'blind wolf teeth,' can be detected as firm nodules under the buccal mucosa rostral to the first cheek tooth. These are often painful and at times are covered with ulcerated mucosa.

The role of wolf teeth in causing oral discomfort has been widely debated.^{36–38} Tradition and client/trainer pressure are the greatest indications for extraction of these vestigial teeth.³⁸ Certainly, most wolf teeth cause no problem to the



Fig. 17.10 Local anesthetic (1–2 ml) administered around the wolf tooth with a small gauge needle on a short extension set attached to a lure lock syringe.

horse but cause concern to the trainer for several reasons. It is difficult, if not impossible, to properly round the rostral edge of PM2 to accommodate biting with a wolf tooth in place. Displaced or sharp crowned wolf teeth can cause buccal pain and ulceration when biting pressure is placed on the cheeks. Some wolf teeth do become loose or diseased and have been suspected to be a cause of head shaking or biting problems.

Some veterinarians advocate floating or grinding the wolf tooth crown, incorporating it into the bit seat. This has the potential to loosen the tooth or expose the pulp chamber. Both conditions could be detrimental in the long term and predispose the tooth to pulpitis and lead to eventual extraction. It is, however, customary practice to extract wolf teeth in young performance horses. In most cases, with proper restraint and equipment, these single-rooted teeth can easily be extracted from the socket in total. Horses should be sedated and given analgesia or a local anesthetic before these teeth are removed (Fig. 17.10).³⁷ Blind or unerupted wolf teeth can be evaluated radiographically if one is uncertain about their presence or position.

Rarely, a wolf tooth is encountered that is quite large and looks as if it has become molarized like the other cheek teeth.³⁹ These should be evaluated radiographically and, if unopposed, they need to be shortened or extracted. These may prove to be supernumerary teeth, in some cases.

Lower first premolars (305–405) are occasionally detected in the mandibles rostral to the first cheek teeth. These are usually quite small and may only be a small tooth sliver detected soon after the deciduous teeth have been shed. However, they can be large with sharp crowns (Fig. 17.11). Lower first premolars have caused problems in bitted horses. Their presence should always be noted during an oral examination on a performance horse. They can be difficult to see on the oral examination because they may be partially covered by a loose fold of buccal mucosa at the lip commissures. Digital palpation just rostral to the first lower cheek tooth is the most accurate way to detect these short-crowned teeth. Unerupted lower wolf teeth are rare and may only be detected radiographically. These teeth can be elevated using

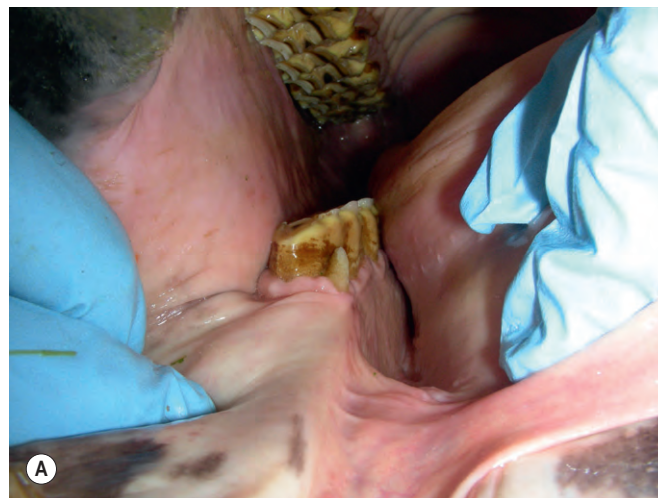


Fig. 17.11 (A) Lower wolf tooth (405) lingual to the crown on 406. (B) Extracted 405 with a long, slender root.

the same techniques as for the uppers. Extraction techniques for removal of wolf teeth are covered in Chapter 20.

In the 2.5- to 5-year-old horse, the 24 deciduous incisors and premolars are replaced by permanent teeth. Horses have vertically successional teeth. Therefore, each deciduous tooth and its underlying permanent tooth reside in the same alveolar crypt. The development and eruption of the permanent tooth lead to resorption of the roots of the deciduous tooth. This, combined with attrition of the clinical crown, results in shedding or exfoliation of the deciduous tooth (also known as a 'cap'). Conditions such as permanent tooth displacement, diastemata formation, and dental impactions are often attributed to disorders of tooth eruption. The equine teeth in each arcade are in tight apposition and act as a single grinding unit. It is easy to see how maleruption or displacement of a tooth can result in loss of integrity of an arcade. This would predispose to both abnormal crown wear and periodontal disease.⁴⁰ Some practitioners have expressed concern about the role of early or delayed eruption of

permanent teeth playing a role in the formation of certain abnormal dental wear patterns noted later in life (i.e., dominant maxillary 10s, lower 08–09 wave, incisor smile, or frown, etc.).

Incisor caps normally shed from the most mesial teeth (01s) at about 2.5 years (between 30 and 34 months), from the 02s at about 3.5 years (40–44 months), and from the corners (03s) at about 4.5 years (54–60 months of age). Miniature horses and ponies may not erupt permanent incisors for 6–18 months later than Thoroughbred horses. The permanent incisors often erupt slightly palatal to the deciduous tooth. Therefore, the incisor cap often retains the more labial portion of the root and is often displaced slightly rostral in the socket as it is shed.

Retained deciduous incisor teeth may be a source of discomfort in the 2–5-year-old horse. Head tossing while eating or rubbing the incisors on the stable wall and/or feed box can result from retained incisor caps or root slivers. Incisor caps are easily removed with small extraction forceps. Retained root slivers may need to be removed with a root elevator while the horse is sedated. Retained and displaced deciduous incisors can appear as a double tooth or a double arcade of teeth, which should be differentiated from supernumerary permanent teeth. Uneven eruption of permanent incisors has been reported as a predisposing factor in incisor malalignment and uneven wear. Premature extraction, trauma, or avulsion of a deciduous incisor tooth has resulted in maleruption, malformation, or failure of eruption.⁴¹

The sequence of eruption of permanent equine cheek teeth has been widely reported in the literature with emergence times of 2.5 years (813 days) for PM2, 3 years (1095 days) for PM3, and 4 years (1460 days) for PM4.³⁴ Recent work has shed new light on premolar eruption times at least in the Thoroughbred horse. In this study, male animals had a younger age of emergence of 06s by 34 days compared to females. Teeth in the lower jaw had a younger age of emergence by 14 days compared to the same teeth in the upper jaw. The study showed the 06s emerging about 1055 days of age, 07s at about 1130 days of age and the 08s at about 1350 days of age.⁴²

Worn crowns of the deciduous premolar teeth (caps) become loose and subsequently either displaced or shed into the mouth. These wafer-thin portions of deciduous tooth crown can have a variable number of root slivers (Fig. 17.12). The caps can appear much like a table with four legs lying over the top of the permanent tooth. Gingivitis and periodontal disease can result if these root slivers are broken off and remain in the subgingival space after the cap is shed.

The eruption pattern of permanent molarized dentition follows a sequence that predisposes to entrapment (impaction) of deciduous PM3 and PM4. Delayed shedding of deciduous premolars can predispose to gingivitis and periodontal disease. Retained, split, or displaced deciduous premolars can be distracting to the training process of a young horse. Additionally, retained deciduous premolars may cause distastication, anorexia, and predispose to malocclusion and abnormal crown wear of the permanent teeth.^{40,43} In some cases they have been recognized as a factor in dorsal displacement of the soft palate.⁴⁴ If one cap has shed, the cap in the opposite side of the jaw should be evaluated and, if loose or close to exfoliation, removed. Impacted caps, manifested as bony enlargements or eruption bumps



Fig. 17.12 (A) Root slivers of this premolar cap (508) can become lodged in the gum if they break off when the tooth is shed. (B) Broken (508) root sliver embedded buccal to the permanent tooth.

on the ventral mandibular ramus or maxilla rostral to the facial crest, can result from lingual displacement or delay eruption of permanent teeth. These facial bony enlargements are only cosmetic problems in most cases. However, they can become pathological if eruption is severely inhibited or blood-borne bacteria inhabit the inflamed or ischemic dental pulp. This can lead to anachoretic pulpitis and facial swelling with a draining tract on the mandible or maxilla.⁴⁵ Caps should be evaluated by palpation and visual inspection, using a dental mirror or endoscope (Fig. 17.13). In some instances, open mouth radiographs may be required to evaluate the retained cap and the status of the underlying permanent tooth. Occasionally, caps may extend above the occlusal surface of the adjacent teeth but cannot be extracted without using excessive force. These caps should be floated level with adjacent occlusal surfaces and evaluated 6–8 weeks later.

Various forceps, elevators, and dental picks are available to aid in the diagnosis and treatment of retained deciduous teeth. These include Reynolds cap extractor forceps (upper and lower), molar forceps (11 inch), No. 34 gouge dental elevator, and No. 69 dental extraction forceps. To remove the cap of deciduous PM2 and PM3, small extraction forceps



Fig. 17.13 An intraoral mirror is used to evaluate a 506 cap. The corresponding permanent tooth (106) is seen just erupting through the gum beneath the cap.

work well. On the PM4 cap, open head molar extraction forceps possess a better angle with which to clamp the cap. The forceps are clamped firmly on the base of the cap and pulled lingually across the arcade and the tooth extracted. Care should be taken not to place the forceps below the level of the gums as the palatine vessels along the upper arcade could be disrupted upon clamping, resulting in severe hemorrhage. Rolling the cap toward the lingual surface reduces breakage of the buccal roots, which can leave slivers of the cap behind. With this method, only the lingual cap roots may break. The residual lingual slivers can be easily removed with a root elevator. If slivers do exist on either the lingual or buccal sides of the premolars, they can be worked out of the gum with a dental pick or plucked out with a set of closed head rongeurs. When caps are removed, the underlying permanent tooth will erupt and should be in wear in 3–4 months. Sharp enamel edges will be present on these teeth in 3–6 months, and the horse should be rechecked and floated at this time.

Canine teeth (104, 204, 304, 404) are usually present in most male horses over 5 years of age. These teeth normally cause few if any problems. In a study of 400 horses, five presented with biting or head carriage problems related to canine teeth. In four cases with displaced, supernumerary, or fractured canines, the teeth were extracted with resolution of clinical signs.⁴⁶ It is suggested that displaced canines that are causing soft tissue irritation or bit interference may be successfully treated by simply rounding to the top of the clinical crown. Care must be taken not to damage the pulp which can lead to pulpitis and eventual death of the tooth. Some mares have small rudimentary canines that generally do not cause problems unless they become loose or accumulate tartar. Long or sharp canines in a stallion or gelding have been blamed with bit interference, the mechanism of which has not been determined.

In the past, tall or sharp canine teeth have been cut and blunted before performing corrective dental procedures, to reduce the likelihood of injuring one's hands and/or wrist. This practice is not in the best interest of the horse and should be discouraged.

Erupting canine teeth in 4–6-year-old horses can cause subgingival pain and bit irritation that has been manifested by head shaking or other bad habits. This problem was reported by Percivall over 100 years ago:

I was requested to give my opinion concerning a horse, then in his fifth year, who had fed so sparingly for the last fortnight, and so rapidly declined in condition in consequence, that his owner, a veterinary surgeon, was under no light apprehensions about his life. He had himself examined his mouth without having discovered any defect or disease, though another veterinary surgeon was of the opinion that the difficulty or inability manifested in mastication, and the consequent cudding, arose from the preternatural bluntness of the surfaces of the molar teeth, which were, in consequence, filed but without beneficial result. It was after this that I saw the horse, and I confess that I was, at my first examination, quite as much at a loss to offer any satisfactory interpretation as others had been. While meditating, however, after my inspection, on the apparently extraordinary nature of the case, it struck me that I had not seen the tusks. I went back into the stable and discovered two little tumors, red and hard, in the situation of the inferior tusks, which, when pressed, gave the animal insufferable pain. I instantly took out my pocket knife and made crucial incisions through them both, down to the coming teeth, from which moment the horse recovered his appetite and, by degree, his wonted condition.⁴⁷

In the mature horse, calculus can build up on canine teeth that have lost the crown enamel. These teeth should be scaled and brushed to prevent or reduce the degree of gingivitis and periodontal disease (Fig. 17.14).

Special concerns in the treatment of miniature horses, ponies, and draft breeds

Several types of horses deserve special consideration when performing dental procedures. In recent years, small ponies and miniature horses have become popular companion animals and warrant particular attention. Intensive inbreeding to reduce body size and refine the head from a large draft type to a light horse type has led to an increased incidence of dental problems. In genetic studies of other animal species, it has been shown that teeth diminish in size more slowly than the jaws.³⁹ The teeth of a 250 lb miniature horse are about two-thirds the size of a 1000 lb Quarterhorse.⁴⁸ Disproportionately large tooth size in relationship to head size seen in miniature horses can encourage tooth overcrowding and lead to dental maleruptions and malocclusions. This predisposes the small horse to a higher incidence of dental disease and abnormalities of wear.^{40,43} For this reason, early and frequent oral examinations and interceptive dental corrective procedures are more important in smaller horses.

The miniature's small stature and reduced head size makes the oral cavity more difficult to evaluate. Many of these pet horses are poorly trained and require sedation to be restrained. Careful calculations of body weight and sedative medication dosing at a lower mg/kg level are important. Restraint at a level that allows the examiner/operator to be comfortable requires either elevating the horse or lowering

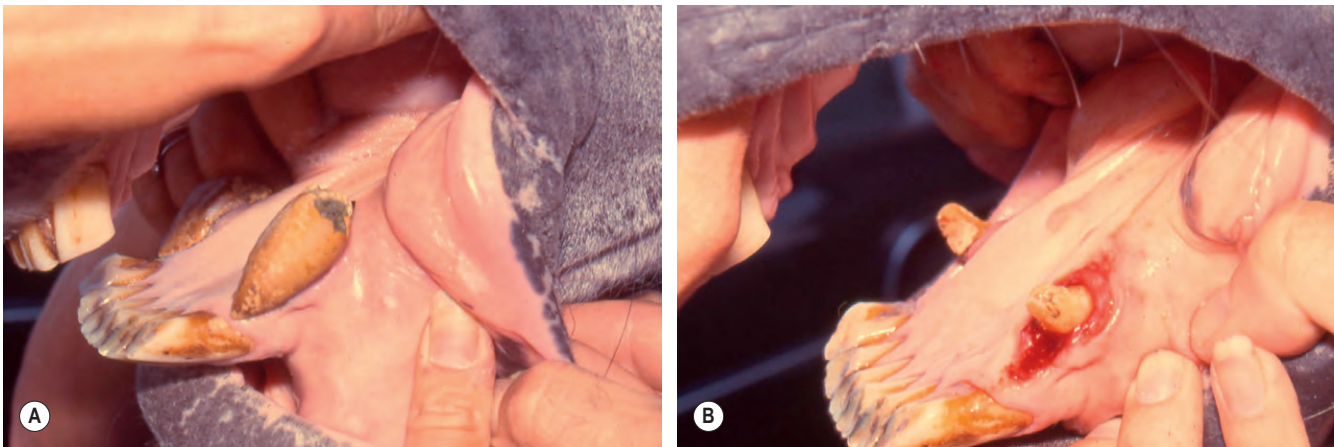


Fig. 17.14 (A) Severe tartar accumulation (calculus) on 304. (B) Calculus has been removed revealing the tooth crown that is no longer covered with enamel. The gingival recession is severe. Radiographs revealed loss of crestal bone.

the veterinarian. These horses can be sedated and restrained at ground level, but this requires the practitioner to work on his knees. Knee pads offer protection, and a solid bar or skirt in front of the horse provides a barrier between the operator and the horse. Elevated stocks or loading dock can bring the animal's head to a more comfortable working height.

Special dental instruments may be required to work in the small oral cavity of miniatures/ponies. Interceptive orthodontics is more often employed in miniature horses because they experience a higher incidence of dental overcrowding. It has been found that early removal of deciduous teeth can result in destruction of permanent tooth buds. This information can be used to the horse's advantage if there is severe overcrowding and no room for a full set of permanent teeth in the dental arcade.⁴⁸ Malformed permanent teeth and severe early dental decay are other sequelae to premature deciduous tooth removal, most commonly seen affecting the upper premolars.

Draft and large warmblood breeds present special dental considerations due to their weight and size. Large horses weighing over 750 kg usually require less medication for sedation on a mg/kg basis, than medium-sized animals. A head support stand or a metal-framed dental halter suspended from a sturdy beam is necessary to support the additional weight of the heavy horse's head. A sedated draft horse can become unsteady or stumble, which can be extremely dangerous for the veterinarian or his assistant(s). Sturdy stocks are recommended as a safe area for restraint. The operator may need a platform on which to stand in order to maintain an ergonomic working posture. Large horses may overpower a regular McPherson type speculum, and the larger MacAllen or Conrad speculums give the operator more security and safety when placing hands and arms into the caudal recesses of the mouth. The Series 2000 speculum is heavy and can be purchased with a draft horse poll strap. If hand floating, long shaft instruments are required to reach the caudal aspect of the cheek teeth. Special 24-inch-long shafts with bonded or interchangeable blades are available from at least one instrument manufacturer. Power equipment is especially convenient for working in large, deep mouths. The disk burr floats with long shafts have been found to be extremely versatile and efficient for working on draft horses (Fig. 17.15).

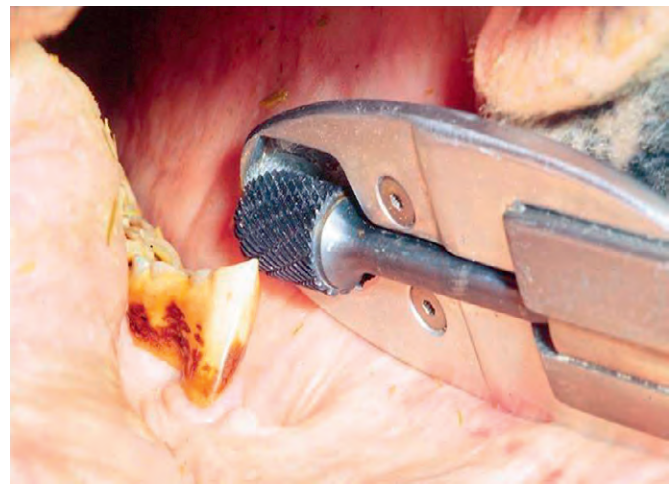


Fig. 17.15 Motorized dental burrs with long shafts. This instrument works well for reaching the caudal recesses of the mouth in large breeds.

In large breeds, deciduous tooth shedding may be delayed up to several months compared to the light breeds. This further postpones cap removal. The incidence of certain congenital craniofacial deformities (wry nose and parrot mouth) has been over-represented in draft breed horses.⁴⁹ There appears to be a disproportionately large number of draft horses with molar arcade malocclusions leading to hook formation on the upper 06s and lower 11s. Clydesdale horses have a distinct 'mustache' appearance of the upper lip and many have large, even molarized, wolf teeth (105, 205). These large wolf teeth often require removal for correction of biting problems. Preoperative radiographs and infiltration of local anesthetic agents are helpful in planning and successfully carrying out extractions.

Correction of cheek teeth and incisor overgrowths

The process of reducing dental protuberances to adjust the dental arcades has been practiced for centuries. Percussion

type instruments described as molar cutters or chisels have been used for at least 200 years. Abnormal wear patterns develop secondary to poor dental occlusion or altered masticatory patterns. It is beneficial to explore the cause of the wear abnormality before corrective action is instituted. It should be determined whether the wear abnormality rendering the table surface uneven is a result of an overgrowth of a tooth crown or excessive attrition or lack of tooth crown. The classic types of cheek teeth abnormalities of wear are described as step mouth (tall teeth), hooks, wave mouth, exaggerated transverse ridges, and shear mouth. Common abnormalities of incisor wear include elongated teeth secondary to overjet, diagonal bite, smile or frown bite, and isolated tall teeth.^{13,21}

Balancing a horse's mouth is more than simply reducing the crown on tall teeth. Dental arcade balancing or equilibration allows the jaw to move symmetrically through the full range of mastication.⁴¹ The molar arcades, oral soft tissues, muscles of mastication, and temporomandibular articulation should function as a unit. Factors such as head conformation, facial asymmetry, previous trauma, dental attrition, and craniofacial deformity (congenital or developmental) determine how close to ideal dental balancing can be achieved. Keep in mind, changing the crown shape of a tooth changes the way the tooth functions in the arcade. With even a small alteration of the dental table, all associated structures of mastication (i.e., teeth, bone, muscles, tongue, and palate) must adjust. Indiscriminate use of instruments in the mouth by individuals untrained in the principles of dental anatomy, physiology, and pathophysiology can cause harm to the dental apparatus. Corrective procedures dealing with the occlusal surfaces of teeth should be conservative until one has a thorough working knowledge of not only anatomy and mastication but tools specifically developed for correction. The principles in treating all dental elongations are the same for any tooth. Reduce the tall tooth to take the damaged or worn surface of the opposite arcade out of occlusion and allow for less restricted rostrocaudal and lateral jaw motion.⁹ Each tooth in the dental arcade taken out of occlusion by reducing the exposed crown height places excessive masticatory forces on the teeth that remain in occlusion.

Hypsodont teeth out of occlusion with teeth in the opposite dental arcade become tall or protuberant from lack of crown wear or attrition. Congenital or developmental conditions resulting in unopposed teeth include supernumerary teeth or the absence of a tooth or several teeth in a molar or incisor arcade. Acquired conditions with this same result include teeth that have been surgically removed from one arcade or severe crown damage or fracture that has occurred; the unopposed tooth/teeth become elongated due to lack of attrition.^{50,51}

A single unopposed tooth becomes longer over time and can cause pronounced negative effects on mastication. This condition is often referred to as 'step mouth.' Long crowns can reach the soft tissues of the opposite jaw and lead to mucosal ulceration, osteomyelitis, or sinus empyema. It is important to detect unopposed teeth early and keep the table surfaces even. This is easy to do during regular dental check-ups. If the teeth are not attended to on a regular basis, great difficulty may be encountered in attempting to reduce extremely tall teeth. Many power dental instruments



Fig. 17.16 Guarded carbide dental burr used to reduce a dental elongation on the rostral aspect of 306.

available today are quite efficient in reducing tall teeth crowns (Fig. 17.16). These instruments should be used with caution so as not to overheat the tooth or abrade the soft tissues of the mouth. Some tall teeth, especially those in the caudal recesses of the oral cavity, may be difficult to reach with some power tools. Molar cutters and obstetrical wire may be useful in correcting some caudal elongations, but extreme care must be exercised not to fracture the crown or expose a pulp horn.

Equipment selection and placement are critical when using molar cutters to reduce tall teeth. Cutters should be sized to fit the tooth to be reduced, with blades set parallel to each other when pressure is placed on the buccal and lingual edges of the crown. The cutter blades should be placed parallel to the normal occlusal surface of the dental arcade. The tooth should be reduced with quick pressure taking care not to twist the cutter. The objective is to cleanly remove the tall tooth crown without damaging the remaining tooth. Problems seen after molars have been cut include fissure fractures down the crown and associated periodontal pockets, tooth extractions, and pulp exposure. Molar cutters have either simple or compound action. A simple cutter with B- or C-head works well for most mandibular cheek teeth. A compound D-head cutter is more effective in fracturing maxillary cheek teeth. The upper molars are wide, and the upper incisor teeth and speculum plates limit access to a long, straight-handled cutter. An open head cutter with an offset 20° angle works well to reach some maxillary cheek teeth. After cutting, the affected tooth should be palpated and probed to ensure the intact section has not been loosened or fractured. The table surface should be smoothed and leveled with a rasp. If pulp horns have been exposed, a vital pulpotomy and crown sealing are required.

Dental hooks, if present, are located on the rostral or caudal aspects of the molar arcade. They are typically the result of a malocclusion of the upper and lower jaws and can be associated with congenital or developmental disorders. Rostral or caudal displacement of the maxillary arcade or a disparity in length of cheek tooth rows results in a hook. Hooks grow and develop at a variable rate but do so in

proportion to the eruption rate of the involved tooth. Most teeth that develop hooks are in partial occlusion, and supereruption is seldom a factor in the rate of hook formation. The length and table surface of premolar and molar hooks increase over time. Hooks alter mastication and place abnormal forces on the teeth and jaws.

Close and regular attention to malocclusions and abnormal wear patterns, with timely correction, keeps elongations from forming. Not all horses have routine dental care, and some develop large hooks over time. The position, size, and extent of the hook should be assessed, as should its mechanical effect on periodontal structures of the affected tooth and opposing teeth. Additionally, the pattern of mastication should be taken into account. Some hooks are bilateral and symmetric to all four molar quadrants. Large hooks can have a detrimental effect on the alignment of the incisor tables from abnormal forces placed on the jaws. Small hooks that consist mostly of enamel can be easily reduced with a carbide float. Large hooks that consume a greater portion of the table surface contain a high percentage of dentin and are much more difficult to rasp. Hooks can be narrow but quite long, as is the case in horses with slight malocclusions. Some hooks comprise almost the entire tooth. This type of hook is more common in horses with missing or extra teeth in a dental row. The hook should not be reduced below the level of the normal molar table surface.

Percussion instruments, both cutters and chippers, have been used successfully to reduce hooks. These instruments should be used with great caution and precision as teeth have been broken, loosened, and/or repelled as a result. The most efficient and safest way to remove hooks is with the use of motorized dental grinders. These instruments use high-speed rotary burs made of tungsten carbide or diamond grit to grind down the tall crown surface of the tooth.^{32,33,52}

Front hooks in the upper or lower arcade are usually reduced without difficulty. The cheeks and lips should be protected from the burr and visualization is aided by a good head light. Air or water should be used to reduce the amount of heat and dental dust generated when burring. Rear hooks are usually associated with a ramp or wave in the back of the mouth. It is helpful to reduce other elongations rostral to the hook before correction is attempted. The majority of rear hooks can be reduced with a solid carbide blade mounted on a long-handled, straight float. The blade should be set to cut on the pull stroke. The float is pushed to the back of the mouth until it rests on the top of the hook. A pull stroke is used to rasp the crown of the tooth. Small thin caudal hooks can be removed with an Equi-Chip. Several motorized instruments with 18–24 inch long guarded heads have been successfully used to remove back hooks. Once the hooks are reduced, forces placed on the jaws and the pattern of mastication change.

Incisor occlusion and lateral jaw excursion (EMC) should be evaluated before and after corrective procedures. A gradual upward sloping at the end of the arcades is referred to as a ramp. Many horses have the caudal lower molars erupt in the curve of the jaw. This is a normal anatomic feature in some horses and these ramps should be carefully evaluated before any crown reduction is undertaken. Special precautions should be taken if molar cutters are used to reduce rear hooks. The caudal pulp horns are easily opened when caudal hooks are reduced. This author has seen several cases of

lower M3 apical abscesses that were attributed to crown reductions that damage the pulp horns.

'Wave mouth' is the term used to describe an undulating pattern usually involving the central portion of the dental tables. This condition is seen in horses of any age. Waves usually involve elongated lower 08s and 09s with correspondingly worn, cupped-out, or decayed upper 08s, 09s, or 10s. Waves can also form as a result of missing, misplaced, deviate, or rotated teeth in the opposing dental arcade.⁵⁰ It is important to assess the cause of a wave in order to develop a plan for management. Long teeth are seldom an isolated event in the mouth but they affect the pattern of mastication and wear of all other teeth. It is important to note how many teeth are involved in the protuberant area. Rarely is only a single tooth overgrown. The usual rate of dental eruption can be increased if the involved tooth is completely out of occlusion with the opposing teeth. Completely unopposed teeth have been seen to erupt at a rate of 0.5–2 cm a year, two to four times the normal rate of eruption. Unopposed teeth do not have the normal occlusal surface stimulation to form secondary dentin, so the sensitive pulp is often closer to the occlusal surface. The most common wave seen is the slowly progressing condition of aged horses. Infundibular enamel loss or central crown attrition reduces the upper cheek teeth, and the wave may become quite tall as the upper cheek teeth wear down to the root and eventually become smooth (see Ch. 18).

Slight wave formations of the dental table can be corrected with a float or rasp. The horse's mouth must be held open with either a speculum or wedge to gain access to the table surface of the arcade. The use of tungsten carbide blades makes small wave reduction easy, while power floats and/or grinders are often necessary to reduce extremely tall waves. When reducing a wave it is important not to take down the entire molar table but only the portion involved in the elongation. Keep in mind that by reducing the crown height of the involved teeth, this portion of the dental arcade is being taken out of occlusion. Thus, the masticatory forces are increased on the adjacent teeth. Dental waves are easy to manage if the patient is seen on a regular basis and the crown height is maintained at a normal level.

Abnormal transverse ridges are actually tall wedges of enamel and surrounding hard tissues running buccolingually across the occlusal surface of the tooth. These ridges are usually opposite a small diastema or narrow areas of excessive crown wear or fracture and should be reduced to aid in therapy of the defect that occurs in the opposing arcade. A table float or most any power tool can be used to reduce the elevated portion of the ridge. These should not be confused with regular transverse ridges seen in young horses (3–8 years of age).⁵³ Regular transverse ridges serve a purpose by increasing the surface area of the teeth and are a normal feature in young horses. Normal ridges are not a continuation of the sharp enamel points that form on the buccal cingula of the upper cheek teeth. These ridges can be slightly contoured but no attempt should be made to reduce or flatten the table surface as this can damage the tooth and reduce its longevity. Excessive reduction of the table surface has been known to bring the molar arcades completely out of occlusion. Overzealous reduction of transverse ridges contributes to the unfortunate practice of excessive and repeated incisor reductions.

'Shear mouth' occurs when the occlusal table surfaces of the molar arcades are worn at an extremely steep angle (greater than 45°). When dental occlusion is symmetric through a full range of jaw motion, the molar tables should wear at an even 10–30° slope. When masticatory excursion is limited on one or both sides, the teeth wear at an abnormally steep angle. Horses with loose or painful teeth, jaw malalignment, severe periodontal disease, neurological paralysis of the masticatory muscles, or temporomandibular joint problems that limit jaw motion in one direction, develop shear mouth. Quite often, horses with shear mouth will also exhibit masseter and temporalis muscle atrophy on one or both sides.

Before correcting a shear mouth, the equine practitioner should attempt to identify and correct the underlying cause. Any attempt at correction of the molar table angle abnormality should be addressed only after certain factors are considered:

1. The condition has been present for an extended period of time and the muscles, ligaments, and joints have remodeled to accommodate changed chewing patterns.
2. Steep table angles may be accompanied by a long outer buccal edge of the upper arcade (up to 4 cm) and a very short palatal edge that may progress up into the gum line. A corresponding long, sharp edge usually forms on the lower arcade.
3. The tall, scissor-like conformation of the dental arcades may prevent opening the mouth wide enough to allow visualization or instrumentation in the caudal portion of the mouth.

Correction of shear mouth should be attempted in stages, working on the horse's mouth every 1–3 months for three–six visits. The scissor blade wear pattern on the cheek teeth prevents the operator from establishing a normal table angle even if the tall portion of the crown is reduced to a more normal height. Working from the front of the mouth caudally, the molar tables can be contoured. Over time, the muscles and joints adjust with mastication and many affected horses enjoy more normal occlusion and comfortable masticatory function. This condition is irreversible in some horses, and associated dental pathology may be severe. Many of these horses must be managed through dietary adjustments.

Abnormalities of incisors have been blamed for causing difficult mastication and decreased performance. The incisors are easy to observe and can be evaluated with less difficulty than the cheek teeth. The oral examination, prior to any corrective procedures, should include evaluation of lateral jaw excursion to molar contact (EMC). Incisor abnormalities have been separated into five classes:^{54–56}

1. Excessively long incisor arcades from lack of occlusal contact and/or wear
2. Smile bite, or dorsal curvature of the incisor arcade
3. Frown bite, or ventral curvature of the incisor arcade
4. Diagonal bite with or without an offset jaw, and
5. Stepped or irregular incisor bite.

Most abnormalities can be corrected or at least greatly improved with relatively simple procedures and basic equipment. When realigning the occlusal surfaces of the incisor arcade, it is important to keep in mind the relationship

between the incisor and molar arcades and the temporomandibular joints. Before the incisor tables can be properly balanced, the molar tables should be floated and wear abnormalities corrected. Horses are usually more sensitive in the incisor tooth area. Since incisor tooth corrective procedures are often the last to be performed, the horse may require sedation or resedation to complete the task of incisor reduction. For minor incisor work, a twitch may be used to restrain the horse for a short period of time.

Horses with long incisor teeth have a malocclusion of the upper and lower jaws. The congenital defects termed parrot mouth, monkey mouth, and wry nose are the most common reason for these teeth rows to be out of occlusion. Some horses may develop a slight incisor overjet or underjet over time due to abnormal forces placed on the jaws from enlarging rostral 06 and caudal 11 hooks. These elongations, if large, can force the lower jaw in a rostral or caudal direction, which leads to lack of wear on the portion of the incisor tables that is out of occlusion (Fig. 17.17). The technique to correct overlying long incisors involves reducing the exposed crown height of the long teeth. It has been shown that no more than 3 mm should be removed at one time to prevent pulp exposure and avoid drastic changes in the EMC. A simple, logical method for determining how much incisor should be removed has been proposed. Based on this work using trigonometry and measuring lateral jaw excursion and incisor elevation, a fairly accurate estimate of incisor reduction can be determined.^{56,57} Another method often used is estimating the distance in the interocclusal space. This has been defined as the distance between the occlusal surfaces of the upper and lower cheek teeth arcades. To estimate the interocclusal space, the sedated horse's head is elevated and the cheek retracted. Using a penlight or other transillumination device, the distance between the cheek teeth arcades can be estimated.²¹

It has been shown that each 1 mm shortening of incisor length decreases the lateral jaw excursion to molar contact distance (EMC) by about 4 mm. EMC rarely increases following removal of sharp enamel points, but may increase after correction of a severe wave mouth or other major cheek tooth elongations. Measuring EMC pre- and post-treatment enables one to return EMC to the original value after cheek teeth corrections. Long incisor reductions have been performed using flexible shaft, cable grinding tools with solid tungsten, carbide grit, or diamond grit burrs (Fig. 17.18). Diamond cut-off wheels, nippers, and forceps have been used to remove large amounts of incisor crown, but these tools can prove dangerous to the horse and operator. Rotary grinders with carbide burrs or fine carbide or diamond files are the preferred tools for reducing and smoothing incisors. The occlusal surface should be ground down in thin (1–2 mm) layers and then checked for molar table contact and EMC.⁵⁶

Smile bite has been identified as a normal incisor conformation in donkeys.⁵⁸ If it has been found to interfere with mastication, smile bite can be corrected by reducing the corner teeth in the lower arcade (303, 403). Leveling the upper incisors should only be performed if it is determined that reducing them will not create a gap between the upper central (101, 201) and lower central (301, 401) incisors. Frowning incisors are treated in the opposite manner by reducing the corners of the upper arcade (103,



Fig. 17.17 (A) A horse with a slight incisor overjet. Only the upper 01s and 02s are out of occlusion with the lower teeth. The upper 01s and 02s have become elongated from lack of wear. (B) Rostral 106 crown elongation (hook). This tooth has been blunted during floating but the body of the hook is still mechanically forcing the lower jaw in a caudal direction. When these elongations and the corresponding lower 11 hooks were reduced, the incisor arcade came into normal occlusion. The horse could not masticate feed due to a gap between the upper and lower molar arcades. To correct this problem, the upper incisor arcades were shortened 4 mm.

203). Diagonal (or slightly tilted) arcades can be improved or corrected by shortening the upper or lower long or tall incisors. It may be impossible to completely level the more severely tilted incisors without creating a gap between the upper and lower arcades. Incremental shortening of the tall teeth should be performed every 4–6 months until the incisor occlusal surfaces are closer to level from side to side. Recent studies have shown that it is impossible to predict the long-term benefit of correcting the incisor angles in many of these cases.⁵⁹ Stepped (irregular bite) incisors may be locked, with the horse unable to move the mandible laterally without opening his mouth, thus reducing cheek tooth



Fig. 17.18 A carbide chip rotary drum is used to reduce elongated upper incisor teeth.

occlusion and limiting mastication. The incisors can be leveled from side to side by reducing the tall areas as much as 3 mm at a treatment.

The treatment of horses suffering from infundibular decay of the upper cheek teeth is controversial. Through the years, the belief that cemental hypoplasia and infundibular caries could be diagnosed from an oral evaluation of the tooth has led some to advocate filling these defects.^{60–62} To date, the only reasonable management tool is to reduce the tall teeth or wave in the opposite arcade in order to decrease stress on the decayed tooth.

Dental overgrowth has been associated with 62.5% of horses with diastema and is attributed to abnormal occlusal movements caused by painful periodontal disease.⁶³ Becker described treating diastemata by enlarging the space between the teeth to reduce food trapping.⁶⁴ The type of diastema he dealt with has been recently defined as a 'valve' (or closed) diastema.⁶⁵ In this pathological situation, food material is able to enter the triangular defect, bounded rostrally and caudally by tooth, distally by gingiva or the periodontal defect, and proximally by the occlusal surface of the dental arcade. Egress of feed material from this space is impeded by the valve effect and the enlarging abnormal wedge or transverse ridge that often forms on the opposing cheek tooth. Quality regular dental care, appropriate crown reductions, and necessary extractions should be the first phase of therapy. Many horses respond positively to repeated removal of dental associated overgrowths.⁶³ Removal of foreign material (plant awns, impacted or decayed feed, and calculi) in the interproximal spaces and gingival sulci speeds healing in many cases (Fig. 17.19). Flushing dental pockets with a syringe and infusion catheter or elongated water pick has been described.^{20,66} Special long-handled air abrasion units deliver water and medical grade baking soda under pressure, to flush periodontal pockets (Fig. 17.20). In cases where reimpaction of feed is likely, placement of a perioceutic within the sulcus and/or dental impression material in the larger interproximal spaces has shown good results.^{67,68} Special right-angle burrs have been developed to treat valve diastema (Fig. 17.21). They have been used successfully to grind the dental crown on each side of the valve, opening an occlusal space allowing it to self-clean.⁶⁹



Fig. 17.19 A high pressure water irrigation unit with a right angle nozzle is used to flush material from a periodontal pocket between 307 and 308.



Fig. 17.21 A right angle 4 mm diameter burr is used to open a valve diastema between 407 and 408.



Fig. 17.20 A dental air abrasion unit with an elongated shaft is used to flush debris from diastema and periodontal pockets.



Fig. 17.22 Iatrogenic fracture of 101 caused by incisor nipper used for crown reduction.

Complications of dental corrective procedures

Dental corrective procedures should not be attempted by persons unfamiliar with the possible damage improper equipment and/or technique might cause. Simple tooth floating is not an innocuous procedure but can lead to iatrogenic damage to the horse and its dentition. Coarse float blades chip and break the coronal structures of the tooth and open dentin tubules.¹⁷ Horses chewing on floats or dental spoons have been known to fracture or loosen teeth. Floats and other sharp instruments in the mouth can cause soft-tissue damage that can lead to cellulitis and septicemia. Sharp root elevators and dose syringe tips can lacerate the roof of the mouth and cause severe hemorrhage.⁷⁰ Power tools must be grounded and have GFI plugs to prevent possible electric shock to the horse and/or operator. Disinfecting agents used on equipment and for flushing the mouth, must be prepared in the proper dilution to avoid caustic

irritation. Careless or improper use of molar cutters and chippers or incisor nippers can lead to tooth fracture or extraction (Fig. 17.22). Overzealous grinding of teeth to reduce elongations or even in forming bits seats and blunting canine crowns can cause complications, such as open pulp chambers, tooth decay, or tooth loss (Fig. 17.23). Reducing canine teeth to gum level can lead to tongue lolling in some performance horses. Only a licensed veterinarian should administer an intravenous sedative or analgesic to a horse. Interarterial injections have resulted in severe convulsive reactions or death in some cases. Perivascular medication can cause jugular vein phlebitis or thrombosis, which can end the career of an elite equine athlete. Improperly restrained horses (whether sedated or unsedated) have been known to injure themselves, the operators, and other persons in the work area. Iatrogenic jaw fracture has been seen following the use of a full-mouth speculum.

Post-dental-procedure pain is experienced by some horses, especially if aggressive crown reductions are performed with power equipment. Affected horses do not eat well for a few



Fig. 17.23 Iatrogenic pulp horn exposure of 106. This tooth had been reduced with a carbide burr in an attempt to create a 'bit seat'.

days to a few weeks after dentistry. Some veterinarians advocate giving prophylactic non-steroidal anti-inflammatory medication to all dental patients to help prevent this problem.⁷¹ This painful condition has been blamed on temporomandibular joint pain, readjustment of the masticatory muscles after speculum use, loose teeth post procedure, leaving the mouth out of balance, thus overloading isolated teeth in occlusion, or exposed dental tubule pain.^{17,72} These problems are enumerated to emphasize the importance that only veterinarians and veterinary technicians (under the direct supervision of a veterinarian) should perform equine dental procedures. The potential for iatrogenic damage must be kept foremost when performing equine dentistry. The equine practitioner's job as steward of the horse must be 'to do no harm.'

Timetable for routine dental examinations

The following timetable is a good reference for scheduling routine dental examinations and general maintenance.⁷³

- Birth.** Examine for: 1) congenital defects of the lips or palate; 2) tongue motion and strength; 3) dental malocclusions; and 4) body system abnormalities. Recommended procedures are to provide genetic and orthodontic consultation and perform corrective surgery if necessary. Look for other problem signs, such as underdeveloped carpal or tarsal bones, ruptured extensor tendons, and hernias.
- 6–8 months.** Examine for: 1) incisor and premolar occlusion (all incisors should have erupted); 2) missing teeth; 3) sharp enamel points or hooks; and 4) ulcers on the tongue and buccal mucosa. Recommended procedures are to provide orthodontic consultation and float teeth, if necessary.
- 16–24 months.** Examine for: 1) upper and lower wolf teeth eruption; 2) points and hooks on premolars; and

3) bit lesions. Recommended procedures are to float teeth and round off the rostral corners of the second premolars. Extract wolf teeth.

2–3 years. Examine: 1) upper and lower wolf teeth or blind wolf teeth; 2) deciduous tooth eruption – central incisors and premolars; 3) bit injuries at the corners of the mouth and interdental spaces; and 4) points or hooks on molars and premolars. Recommended procedures are to float outside of upper and inside of lower cheek teeth, remove caps, if present and ready for removal, and extract wolf teeth. Rostral corners of upper and lower second premolars should be rounded if the horse wears a bit.

3–4 years. Examine 1) corners of the mouth and interdental space for bit injuries; 2) incisors for retained deciduous teeth or supernumerary teeth; 3) molars and premolars for points and retained third premolars (second cheek teeth); 4) size and shape of the lower jaw; and 5) for presence of blind wolf teeth. Recommended procedures are to remove caps if present, float teeth, and remove wolf teeth.

4–5 years. Examine: 1) incisors for eruption; 2) canine teeth for sharp edges or eruption delays; 3) molar arcade for proper eruption and alignment of fourth premolars; 4) for presence of upper rostral and lower caudal cheek teeth hooks from malocclusion; and 5) for presence of points or sharp edges on cheek teeth. Recommended procedures are to remove deciduous teeth, if ready, grind or rasp hooks, if present, float teeth, and remove mucosa over canines if gingival eruption cysts are present.

5 years and older. Examine: 1) mouth visually and digitally, especially noting hooks and uneven wear; 2) canines for sharp edges and tartar; 3) oral cavity for decay or gingivitis; 4) incisors for even wear; and 5) evaluate lateral jaw excursion. Recommended procedures are to float teeth, remove hooks, correct abnormal wear patterns, and level or shorten the incisors if indicated.

Educate owners and trainers of the need for routine dental examinations. Indicated corrective procedures should be performed before starting any horse in training.

Summary

A thorough visual and manual examination of the equine patient must be performed to identify any abnormalities. Sedating the horse and using a full-mouth speculum facilitate both the examination and corrective procedures. The use of proper dental instruments makes it much easier for both the patient and veterinarian. Dental elongations should be reduced in stages, taking care not to remove more than 3–4 mm of occlusal surface at one time. A dental form should be used to maintain a record of what procedures were performed, what needs to be done in the future, and to itemize the charges.

References

1. Knottenbelt DC. The systemic effects of dental disease. In: Baker GJ, Easley J eds. *Equine dentistry*, 2nd edn. WB Saunders, Philadelphia, 1999, pp 127–138
2. Tell A, Engenvall A, Lundstrom T, et al. The prevalence of oral ulceration in Swedish horses when ridden with bit and bridle and when unriden. *Vet Journal* 2008; 178(3): 405–410
3. Ralston SL, Foster DL, Devers T, et al. Effect of dental correction on feed

- digestibility in horses. *Equine Vet J* 2001; 33: 390–393
4. Gatta D, Krusic L, Casini L, et al. Influence of correcting teeth on digestibility of two types of diets in pregnant mares. In: *Proceedings, 14th Symposium Equine Nutrition and Physiology Society*, 1995, pp 326–331
 5. Krusic L, Easley J, Pagan JD. Influence of correcting teeth on daily food consumption and glucose availability in horses. In: *Proceedings, Symposium Horse Diseases*, 1995, pp 53–68
 6. Carmalt JL, Townsend HGG, Jazen E, et al. Effect of dental floating on weight gain, body condition score, feed digestibility. *J Am Vet Med Assoc* 2004; 225: 1889–1893
 7. Carmalt JL, Allen A. Relationship between equine cheek tooth occlusal morphology, apparent digestibility, and ingesta particle size. *Am Assoc Equine Pract Proceedings* 2008; (54): 386–389
 8. Tamzali Y. Chronic weight loss syndrome in the horse: a 60 case retrospective study. *Equine Vet Education* 2006; 18: 289–296
 9. Carmalt JL, Townsend HGG, Allen AL. Effect of dental floating on the rostrocaudal mobility of the mandible of horses. *J Am Vet Med Assoc* 2003; 5: 666–669
 10. Bonen SJ. Three-dimensional kinematics of equine temporomandibular joint. Master's Thesis, Dept of Mechanical Engineering, Michigan State University, East Lansing, 2001
 11. Allen T, Jeffery D, Moriarity LA. Routine procedures. In: Allen T, ed. *Manual of equine dentistry*. Mosby, St Louis, 2003, pp 109–156
 12. Johnson LE. Equine dentistry. In: Bone JF, Catcott EJ, Gabel AA, Johnson LE, Riley WF, eds. *Equine medicine and surgery*. American Veterinary Publications, Santa Barbara, 1963, pp 739–760
 13. Easley J. Dental corrective procedures. *Vet Clin North Am: Equine Practice* 1998; 14(2): 411–432
 14. Rucker BA. My approach to motorized equine dentistry using the Powerfloat. In: *Operator's manual, Powerfloat, D & B Equine Enterprises*, Calgary, 2003
 15. Rach D. *Operator's manual, D & B Equine Enterprises*, Calgary, 2003
 16. DeForge DH. Physical ergonomics in veterinary dentistry. *J Vet Dent* 2002; 19: 196–200
 17. Kempson SA, Davidson MEB, Dacre IT. The effect of three types of rasps on the occlusal surface of equine cheek teeth: a scanning electron microscopic study. *J Vet Dent* 2003; 20(1): 19–27
 18. Baker GJ, Allen ML. The use of power equipment in equine dentistry. *Am Assoc Eq Pract Proceedings* 2002; 48: 438–441
 19. Dacre KJP, Dacre IT, Dixon PM. Motorized equine dental equipment. *Equine Veterinary Education* 2002; 14: 263–266
 20. Judd RC. Equine dental prophylaxis using a pneumatic system. *Comp Cont Edu* 2002; 24(1): 62–70
 21. Scrutchfield WL. Dental prophylaxis. In: Baker GJ, Easley J, eds. *Equine dentistry*. WB Saunders, London, 1999, pp 185–205
 22. Stubbs RC. Dentistry of equine cheek teeth. *Am Assoc Eq Pract Proceedings* 2004; 50: 1–6
 23. Allen T. Incidence and severity of abrasions on the buccal mucosa adjacent to the cheek teeth in 199 horses. *Am Assoc Eq Pract Proceedings* 2004; 50: 31–36
 24. Easley KJ. Equine canine and first premolar (wolf teeth). *Am Assoc Eq Pract Proceedings* 2004; 50: 13–18
 25. Scoggins DR. Bits, biting and dentistry. In: *Am Assoc Eq Pract Proceedings* 2001; 47: 138–141
 26. Merillat LA. Animal dentistry and diseases of the mouth. In: *Veterinary Surgery, Vol. 1*, Alexander Eger, Chicago, 1905, p. 189
 27. Wilewski KA, Ruben L. Bit seats: a dental procedure for enhancing performance in show horses. *Eq Pract* 1999; 21: 16
 28. Engelke E, Gasse H. An anatomical study of the rostral part of the equine oral cavity in respect to position and size of a snaffle bit. *Eq Vet Edu* 2003; 5(3): 200–205
 29. Johnson TJ. Surgical removal of mandibular periostitis (bone spurs) caused by bit damage. *Am Assoc Eq Pract* 2002; 48: 463–466
 30. Easley J. Oral and dental disease. In: Hinchcliff KW, Kaneps AJ, Geor RJ, eds. *Equine sports medicine*. Saunders, Edinburgh, 2004, pp 1027–1036
 31. Fisher D, Easley KJ. Floating: making equine dentistry a practice profit center. *Large Anim Vet* 1994; 49: 16–22
 32. Dixon PM. Removal of equine dental overgrowths. *Eq Vet Edu* 2000; 12(2): 68–81
 33. Pence P, Wileuska K. Mature horse dentistry. In: Pence P, ed. *Equine dentistry – a practical guide*. Lippincott, Williams and Wilkins, 2002, p. 141
 34. Sesson S. Digestive system of the horse. In: *The anatomy of domestic animals*, 2nd edn. WB Saunders, Philadelphia, 1921, p. 395
 35. Nickel R, Schummer A, Seiferle E. *The viscera of domestic animals*, 2nd edn. Verlag Paul Parey, Berlin, 1979
 36. Lane JG. A review of dental disorders of the horse, their treatment and possible fresh approaches to management. *Eq Vet Edu* 1994; 6: 13–21
 37. Grove T. Extractions and simple oral surgeries in equines. In: *Proceedings of Eastern States Veterinary Conference, Vol. 5*, (1991), 337
 38. Gaughn EM. Dental surgery in horses. *Vet Clin North Am: Equine Practice* 1998; 14(2): 387–388
 39. Colyer JF. *Variations and diseases of the teeth of animals*, rev edn. Cambridge University Press, Cambridge, 1990, pp 121–122
 40. Caldwell LA. A review of diagnosis, treatment and sequelae of incisor luxation fractures in horses (from a dentist's viewpoint). *Am Assoc Eq Pract Proceedings* 2006; 52: 559–564
 41. Ramzan PHL, Palmer L, Barquero N, et al. Chronology and sequence of emergence of permanent premolar teeth in the horse: Study of deciduous premolar 'cap' removal in Thoroughbred racehorses. *Equine Vet J* 2009; 41: 107–111
 42. Earley ET. How to manage maleruptions of upper fourth premolars in the miniature horse. *Am Assoc Eq Pract Proceeding* 2007; 50: 7–12
 43. Faragella F. Rotated maxillary fourth premolar in a horse. *J Vet Dent* 2004; 21: 226–227
 44. Marr T, Love S, Schumacher J, Walson E. *Equine medicine, surgery and reproduction*. WB Saunders, Philadelphia, 1998, p. 106
 45. Easley J. Recognition and management of the diseased equine tooth. *Am Assoc of Eq Proceedings* 1991; 37: 129–139
 46. Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease part 1: A long term study of 400 cases: disorders of incisor, canine and first premolar teeth. *Eq Vet J* 1999; 31(5): 369–377
 47. Percivall W. Hippopathology. In: Mechener CB, ed. *Special report on diseases of the horse*. US Dept of Agriculture, Washington, 1911 (1852), pp 42–43
 48. Mitz C, Allen T. Dentistry in miniature horses. In: Allen T, ed. *Manual of equine dentistry*. Mosby, St. Louis 2003; 175–192
 49. Vandersplasse M, Simeons P, Bouters R, et al. Etiology and pathogenesis of congenital torticollis and head scoliosis in the equine fetus. *Equine Vet J* 1984; 16: 419
 50. Dixon, PM, Tremaine WH, Pickles K, et al. Equine dental disease part 3: a long term study of 400 cases: disorders of wear, traumatic damage and idiopathic fractures, tumors and miscellaneous disorders of the cheek teeth. *Equine Vet J* 2000; 32(1): 9–18
 51. Dixon PM, Tremaine WH, Pickles E. et al. Equine dental disease part 4: a long term study of 400 cases: apical infections of cheek teeth. *Equine Vet J* 2000; 32(3): 182–194
 52. Johnson TJ. Correction of common dental malocclusions with power instruments. In: Robinson NE, ed. *Current therapy in equine medicine*, 5th edn. WB Saunders, Philadelphia, 2003, pp 81–87

53. Dixon PM. Dental anatomy. In: Baker GJ, Easley J, eds. *Equine dentistry*, 2nd edn. Elsevier, Edinburgh, 2005, pp 40–43
54. Scrutchfield WL. Incisors and canines. *American Association Equine Practitioner Proceedings* 1991; 37: 117–121
55. Rucker BA. Modified procedure for incisor reduction. *American Association Equine Practitioner Proceedings* 1995; 41: 42–44
56. Rucker BA. Incisor and molar occlusion: normal ranges and indications for incisor reduction. *American Association Equine Practitioner Proceedings* 2004; 50: 7–12
57. Rucker BA. Utilizing cheek teeth angle of occlusion to determine length of incisor shortening. *American Association Equine Practitioner Proceedings* 2002; 48: 448–452
58. duToit N, Burden FA, Dixon PM. Clinical dental examinations of 357 donkeys in the UK: part 1 – prevalence of dental disorders. *Equine Vet J* 2008; 138
59. DeLorey MS. A retrospective study of 204 diagonal incisor malocclusion corrections in the horse. *J Vet Dent* 2007; 24: 145–149
60. Swanstrom OG, Wallford HA. Prosthetic filling of a cement defect in premolar tooth necrosis in a horse. *Veterinary Medicine/Small Animal Clinician* 1977; 1475–1477
61. Klugh DO. Updating infundibular decay in equine cheek teeth. In: *Conference Proceedings 16th Veterinary Dental Forum*, Savannah, GA, 2002, pp 238–239
62. Greene S. Equine dental advances. *Vet Clinics North Am: Equine Practice* 2001; 17(2): 319–334
63. Dixon PM. Equine dental disease part 2: a long term study of 400 cases: disorders of development and eruption and variations in position of the cheek teeth. *Equine Vet J* 1999; 31(6): 519–528
64. Becker E. Cited in Becker E. *Zähne*. 1962 In: *Handbook of specialized pathological anatomy of the horse*. Verlag Paul Parey, Berlin, 1945, p. 146
65. Carmalt JL. Understanding the equine diastema. *Eq Vet Edu* 2003; 3(1): 43
66. Mueller POE, Lowder MQ. Dental sepsis. *Vet Clinics North Am: Equine Practice* 1998; 14(2): 349–363
67. Pence P, Basile T. Dental infections. In: Pence P, ed. *Equine dentistry: a practical guide*. Lippincott, Williams and Wilkins, Philadelphia, 2002, pp 215–219
68. Greene S, Basile T. Recognition and treatment of equine periodontal disease. *American Association Equine Practitioner Proceedings* 2002; (48): 463–466
69. Dixon PM, Barakzai S, Collins N, et al. Treatment of cheek teeth by mechanical widening of diastemata in 60 horses (2000–2006). *Equine Vet J* 2008; 40: 22–28
70. Dixon PM, Hawkes C, Townsend N. Complications of equine oral surgery. *Vet Clin Equine* 2009; 24: 499–515
71. Greene S. Equine dentistry, notes for Advanced Dentistry Laboratory, American Association of Equine Practitioners Annual Meeting, New Orleans, 2003
72. Johnson TJ. Iatrogenic damage caused by modern dentistry procedures. In: *Current Therapy in Equine Medicine*, 6th edn. Robinson and Sprayberry, Saunders/Elsevier, St Louis, 2009, pp 324–327
73. Easley KJ. Equine dental development and anatomy. *Am Assoc Eq Pract Proceedings* 1996; (42): 1–10

Geriatric dentistry

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Introduction

Geriatric equine medicine is that part of medicine that relates to the prevention and treatment of diseases in aged horses. The age at which an equid requires geriatric care varies depending on the breed of the horse (or other equid), management practices and type of work. Horses have an increased prevalence of dental disorders, and in particular of periodontal disease, after 15 years of age.^{1–3} A recent study has shown that many donkeys start to develop serious dental related disorders at 16–20 years of age.⁴ Cheek teeth diastemata, wear abnormalities, overgrowths, displacements, loss of teeth, and other dental disorders, such as periodontal disease, wave mouth, step mouth, and smooth mouth have an increasing prevalence in donkeys older than 20 years of age.⁴ This emphasizes the need for additional preventative dental treatment to equids aged 15 years and older, although such additional care is needed at an earlier age if the animal has pre-existing dental disorders.

Clinical signs associated with dental disease vary with the severity of dental disease, and up to 24% of horses that do not show any dental related clinical signs, have one or more dental abnormalities.⁵ In milder cases, clinical signs may be limited to biting problems or abnormal head carriage during ridden exercise. With more advanced dental disease, equids may display quidding, with boluses of partially chewed forage found on the stable floor. With painful oral lesions, equids may exhibit slow deliberate chewing and make 'slurping' noises instead of the normal 'crunching' noises when masticating. Accumulation of forage boluses between the cheeks and cheek teeth may cause temporary cheek swellings. The presence of long forage fibers and unmasticated, undigested whole grain particles in the feces is also an indication of dental related problems. Eventually, in cases of severe dental disease, equids may have weight loss associated with decreased food intake and inefficient digestion.

Intercurrent geriatric diseases

When presented with a geriatric equid requiring dental treatment, it is important to acquire a detailed medical history

and perform a complete physical examination. Older horses may have concurrent disease of other body systems, especially gastrointestinal, musculoskeletal, and respiratory tract problems.⁶ Laboratory analyses, such as complete blood counts and biochemistry functions, should be performed on initial examination to rule out other concurrent medical or metabolic conditions. The presence of large or non-healing cheek or tongue ulcers should alert practitioners to a possible underlying disease, such as pituitary dysfunction.⁷ Pituitary dysfunction should be considered in geriatric equids exhibiting any related clinical signs as 85% of horses with pituitary dysfunction have been shown to be >15 years of age.⁸ A dental survey in live donkeys demonstrated that older donkeys are more likely to have dental disease, a low body condition score, and have a need for supplemental concentrate feeding.⁹ Furthermore, dental disease has been shown to be significantly associated with colic in donkeys.^{9,10}

Anatomic overall tooth changes

Equid teeth are tapered from the occlusal to apical aspect, and as the teeth progressively wear down and erupt, the erupted (clinical) crown and occlusal surface become gradually smaller on cross-section. The occlusal surface of incisors changes in shape in older equids, initially appearing oval after eruption, then triangular and eventually becoming oval again with extreme age, as described in detail in Chapter 7. The rostral orientation of the caudal cheek teeth and caudal orientation of the rostral cheek teeth compress each cheek teeth row tightly to work as a single functional unit, even despite the initial narrowing of the reserve crown.^{11–14} However, eventually the tapering allows for the development of diastemata between the cheek teeth ('senile diastemata') with food impaction and development of periodontal disease.^{13,15} Radiography of such a case is shown in Fig. 13.13.

The loss of maxillary cheek tooth infundibular enamel results in wearing out of the center of the tooth, leaving it with a thin, elevated peripheral enamel ridge ('cupped out tooth'). The exposure of all three dental tissues (enamel, dentin and cementum) is essential for efficient mastication in equids, as the differential wear rate results in prominent

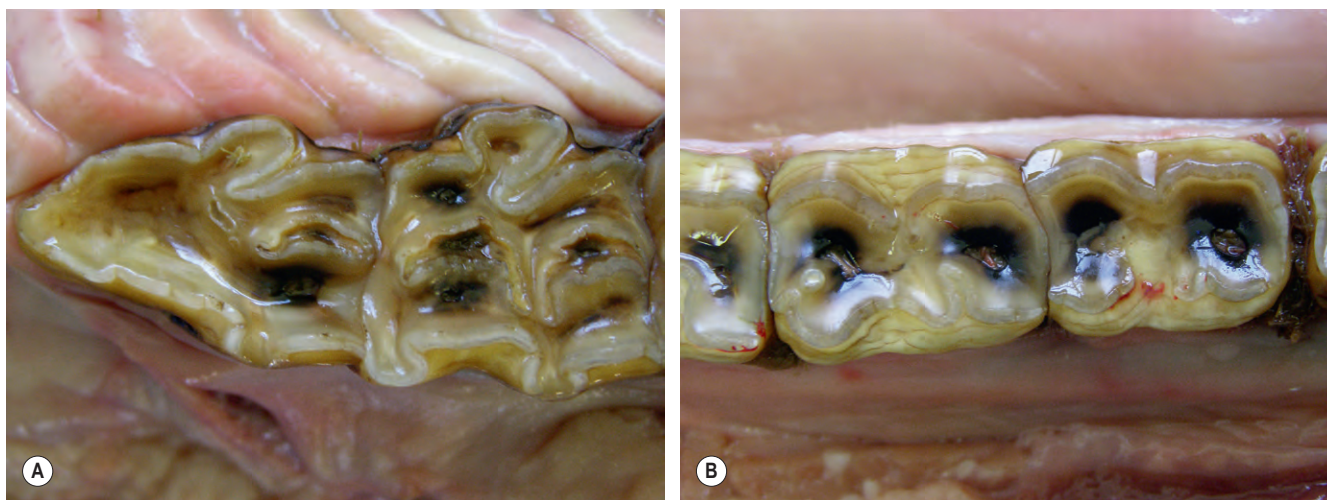


Fig. 18.1 Loss of the rostral infundibulum and 'cupping' of a 106 (A) and loss of peripheral enamel infolding in mandibular cheek teeth (B) in a 31-year-old donkey. Note the occlusal pulp exposures in all the cheek teeth.



Fig. 18.2 End stage of 'smooth mouth' in a 28-year-old donkey with predominantly cemental root remnants of the cheek teeth remaining. Also note the loss of cheek teeth 410 and 411.

enamel ridges and acts as a self-sharpening mechanism. As the teeth are worn to their more apical aspects, the peripheral enamel infolding in mandibular and maxillary cheek teeth becomes less pronounced, before finally wearing out at the junction with the cemental roots (Fig. 18.1). This is characterized by a smooth occlusal surface composed predominantly of cementum and dentin termed 'smooth mouth'.¹³ As these teeth no longer have enamel ridges, they are ineffective at mastication, and as they have no wear resistance from enamel, they are quickly worn away (Fig. 18.2).

In older equids, the decreased occlusal surface area and reduced length of enamel ridges of cheek teeth result in loss of efficiency in grinding food. This is further complicated by the reduced ability to digest protein and fiber that is exhibited in geriatric horses.¹⁶ It is, therefore, essential that geriatric equids have their diet evaluated and adapted according to their dental and general health, and body condition. It has been shown that geriatric horses on a pelleted/extruded

diet with 14% protein content fared better than those fed an 8.5% protein, textured, sweet feed mix.¹⁷ Therefore, the feeding of a good-quality, pre-digested (addition of enzyme) or extruded feedstuff with a protein content of 12–14% would be beneficial to older equids that do not have hepatic or renal disease.¹⁸ If the maintenance of an adequate body condition is a problem, the addition of a vegetable oil or rice bran to the diet will increase the calorific content of the diet, without increasing the level of concentrate feeding.¹⁸ If the efficiency of mastication is greatly reduced as a result of 'smooth mouth' or other dental disorders, the feeding of moistened pellets or cubes to a liquid consistency will improve the amount of feed ingested. Commercially prepared dehydrated chopped hay with 15% crude protein, which is available in the USA, is a suitable diet for many geriatric equids. If availability or economic consideration make this unsuitable, then fiber length may be reduced by processing hay through a wood chipper, leaf mulcher or a lawn mower using a bag attachment.

Sedation and restraint

The presence of concurrent diseases, such as cardiac disease, arthritis, and muscle wasting, needs to be taken into consideration when sedating and restraining geriatric equids for dental treatment. In general, lower doses of anesthetic and sedative agents are required in older horses, as they have increased sensitivity and decreased clearance of commonly used agents.¹⁹ The type and likely duration of dental treatment need to be determined prior to commencement of any treatments to assist in choosing the appropriate restraint methods. If a painful procedure is to be performed, the use of local nerve blocks will decrease the amount of systemic sedation and analgesia that is required.

Low dosages of alpha-2-adrenoceptor agonists, such as xylazine, romifidine hydrochloride or detomidine hydrochloride, in combination with low dosage of butorphanol tartrate for pain control, can be sufficient for most dental procedures in geriatric equids. Although butorphanol has five times the analgesic activity of morphine, the analgesia

persists for only 15–20 minutes. Geriatric equids may be very fractious to extraction of worn, loose teeth, but butorphanol administered just prior to extraction usually provides sufficient analgesia. A continuous IV drip of detomidine or detomidine/butorphanol²⁰ may be used instead of repeated dosing of these drugs. Use of a head support is recommended during dental procedures, but it should be used with stocks or after backing the horse into a corner to minimize slumping of the forelimbs and over-extension of the head, with possible atlanto-occipital subluxation.

Another option if significant dental treatment is required, especially in a fractious patient, is the use of short general anesthesia.²¹ The drawback to general anesthesia is the development of long bone fractures during recovery if insufficient assistance is available to help the horse rise. Protracted malnutrition may produce osteoporosis and so increase the risk of this sequel in older patients.

Heavily sedated geriatric horses, when left alone and unstimulated following dental procedures, are more susceptible to falling off their feet than younger horses. Judicious use of tolazoline HCl (100–200 mg in a slow IV injection) is indicated to partially reverse the effects of alpha-2-adrenoceptor agonists. If the sedation is insufficiently reversed after 15 to 20 minutes, the tolazoline HCl administration may be repeated using half to one-third of the initial dosage.

Incisor disorders

The incisor arcades in older equids often have disorders, such as excessive wear, corresponding overgrowths in the opposite teeth, malocclusions, missing teeth, and displaced teeth. Excessive wear of an entire incisor arcade, most commonly the maxillary incisors, is usually as a result of a behavioral problem, such as crib-biting or wind-sucking. With loss of teeth or excessive incisor wear, repeated regular floating of the opposing teeth is required to maintain a level occlusal surface. Excessive reduction of severely overgrown incisors may expose pulp horns, and it is advisable to reduce overgrown incisors, in stages some months apart, to stimulate normal secondary dentin deposition to protect the occlusal aspect of the pulps. The tapering of incisors towards their apical aspect results in the development of incisor diastemata with the accumulation of food, in some older horses.

Geriatric equid incisors often have abnormal occlusal surfaces, such as a ventral convex curvature ('smile'), a dorsal convex curvature ('frown') or a diagonal (to left or right side) surface ('slant mouth or slope mouth'). These changes are often secondary to disorders of the cheek teeth and a resultant abnormal masticatory action. Once cheek teeth disorders have been corrected, these incisor table abnormalities can be corrected, in stages if severe. 'Smile' mouth appears to be very common in donkeys and was present in 96% of aged donkeys with dental disease and 99% of donkeys without dental disease⁴ (Fig. 18.3). Therefore, smile mouth may be regarded as a normal appearance in aged donkeys and should not be corrected unless inhibiting normal masticatory action.

Functional incisor/molar occlusion in the presence of abnormal incisor occlusal surfaces may be determined by measuring the excursion to molar contact (EMC) distances. EMC is measured by putting the incisors arcades into centric



Fig. 18.3 The typical 'smile' mouth appearance of the incisor occlusal surface observed in most aged donkeys.

occlusion and then pushing the mandible laterally until the upper and lower cheek teeth arcades touch and (due to their angulated occlusal surfaces) the incisors just begin to separate. The distance is measured from the center of the maxillary incisor arcade (interproximal space of 101 and 201) to the center of the mandibular incisors (interproximal space of 301 and 401). The EMC measurements are made on each side. When in centric occlusion, if the center points of the incisor arcades do not align with each other, then the offset distance is either added or subtracted from the center-to-center point measurement (Fig. 18.4).

The average EMC distance for a 450 Kg horse is 12.3 mm.²² This distance, coupled with the average maximum excursion distance of 45 mm \pm 5 mm,²³ demonstrates that a normal equid's masticatory cycle is about 22–25% incisor occlusion and about 75–78% cheek teeth occlusion. Horses with heads shorter than average (Quarter horse length), have an average EMC distance less than 12.3 mm, while the EMC in longer headed horses is greater than 12.3. The mean EMC in miniature horses is about 4 mm, while the mean value in a draught horse is about 16 mm. This difference in EMC in different sized heads is because the pivot point or vertex for lateral excursion is the temporomandibular joint (TMJ). Lines drawn from the TMJ to each of the center points diverge more the further they are from the TMJ and diverge less the nearer they are to the TMJ.

Reducing EMC distances within a range of 12–16 mm should be done carefully, with reduction of tall teeth performed in 1-mm thick stages on tall incisors, before reassessing EMC. A 1-mm reduction in incisor height can decrease the EMC by 4 mm or more. Experience indicates that total reduction should be limited to 3 mm in one session or no more than a 10 mm change in the EMC. Horses with incisor malocclusions having reasonably normal or shorter than normal EMC distances do not need incisor correction; they have functional incisor malocclusions (Fig. 18.5).

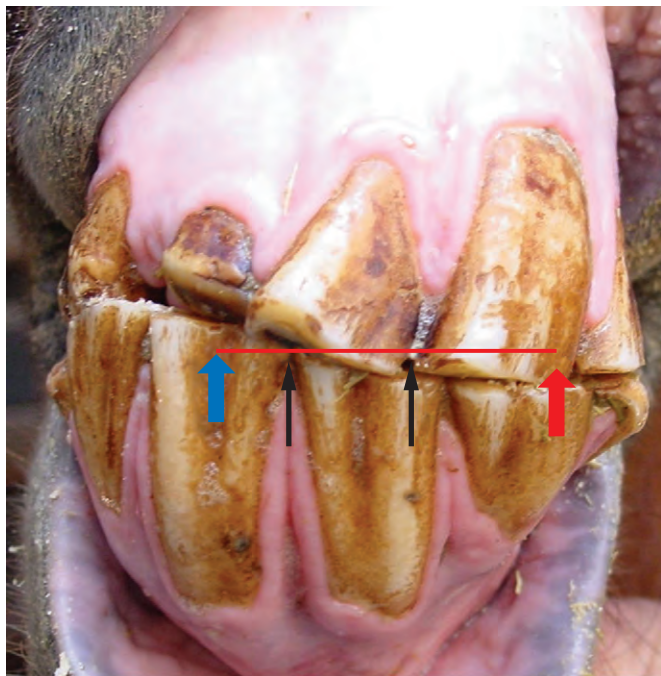


Fig. 18.4 In this 20-year-old Saddle bred horse, the mandibular center point is offset to the horse's right by 10 mm (distance between the black arrows). EMC to the right is 8 mm (18 mm minus the 10 mm offset; blue to adjacent black arrow) and to the left is 24 mm (14 mm plus the 10 mm offset; red to adjacent black arrow). Measurement is made from the center of the maxillary incisors to the center of the mandibular incisors.

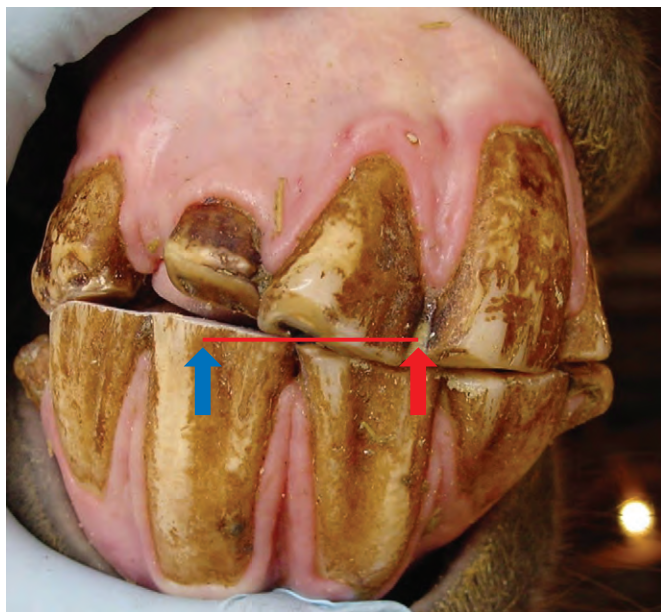


Fig. 18.5 Horse in Fig. 18.4 after correction. 103 (not visible) was reduced by 3 mm; this tooth was displaced caudally and was not interfering with cheek teeth occlusion but was making contact with 404. Teeth 402 and 403 were reduced 2.5 mm. EMC to left is now 14 mm and EMC to right has not changed. The incisors are not level but are now functional, and the horse can chew with more left cheek teeth occlusion.

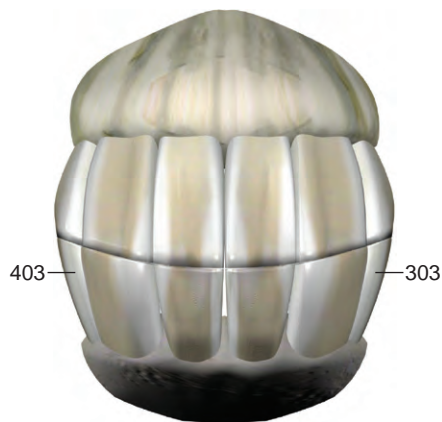


Fig. 18.6 'Smile' malocclusion. Correction is initiated on 303 and 403 by removing 1 mm at the tallest point and tapering toward 301 and 401. (Black wedges). If reduction ceases before 101 and 201 are reduced, incisor contact will be maintained on the 01s and possibly the 02s.

Correction of a 'smile' should begin on the mandibular incisor arcade, removing 1-mm thick layers until the arcade is level, or the reduction (3 mm) or EMC (10 mm) limits are reached (Fig. 18.6). The lateral maxillary incisors are also reduced, if needed. 'Frown' correction reduction is begun on the maxillary arcade then the mandibular arcade, if needed. Correction should always commence on the 03s (corner incisors). If excursion or reduction limits are reached before reduction of the 01s (central incisors) is needed, incisor contact will be maintained on the 01s and possibly part or all of the 02s (intermediates), depending on the severity of the malocclusion.

Periodontal disease

The formation of senile diastemata in the incisors may lead to food impaction and periodontal disease. However, as these teeth are not exposed to any grinding masticatory forces, these diastemata are very rarely associated with deep periodontal pockets. These diastemata and associated (usually) mild periodontal disease can be managed by regular cleaning of the impacted food by the owner. In more severe cases of food impaction, which may be difficult to remove on the caudal aspect of the incisors, these diastemata can be widened using a diastema burr or rotary saw. The accumulation of calculus on the canines and 03s may also cause mild, localized periodontitis, which does not appear to cause any clinical signs (Fig. 18.7). Accumulation of large amounts of calculus can result in more severe gingivitis, with hyperemia and recession of the gingival margin. Removal of the calculus at every dental examination/treatment temporarily relieves the associated periodontal disease. Frequent brushing of the canines by the owners using a normal tooth brush may slow down re-accumulation of calculus.

More recently, a more severe form of incisor periodontal disease has been recognized in geriatric equids that is associated with cemental hyoplasia, and hyperplasia and radiographic lytic changes.^{24–27} The exact etiopathogenesis of this disease has not been determined, but pathological studies show it to be an odontoclastic resorption of affected incisors (also of canine teeth) with subsequent marked deposition



Fig. 18.7 Calculus accumulation on both mandibular canines and the 203s in a 28-year-old donkey. There is mild gingival hyperemia associated with the calculus on 304.



Fig. 18.8 Enlargement of thickness of reserve crown of 203 and 303 (identical to 103 and 403) due to hypercementosis associated with equine odontoclastic tooth resorption and hypercementosis. The horse was asymptomatic, and the disease was identified on oral examination. All the incisors were stable and non-painful to manipulation, but firm palpation of 303 and 403 reserve crowns was painful.

of cement on these teeth, termed equine odontoclastic tooth resorption and hypercementosis (EOTRH; discussed in Ch. 10). Affected animals may present with clinical signs associated with pain, such as masticatory and biting problems, and halitosis (Fig. 18.8). Initially, this condition presents as mild gingival inflammation and edema with small lytic changes in the mid reserve crown incisor on radiographic examination.²⁵ With progression of the condition, draining tracts may develop in the gingiva, and this may be accompanied by gingival recession, or marked subgingival swelling of incisors, reflecting hypercementosis of their reserve crown and apex. Radiographically, progression of the disease is

characterized by lysis of the incisors in an apical direction and an increase in the thickness of the lytic areas to involve the dentin. Loss of interdental bone and widening of the periodontal ligament may also be observed on radiographs. Clinically advanced cases may have painful mobile incisors. Hypercementosis (subgingival nodular enlargements) of portions or all of the subgingival incisors may also be observed on radiographs in some advanced cases (Fig. 18.9).

Due to the predominance of resorptive lesions in this condition, it has been proposed to be more similar to feline tooth resorption than to a primary periodontal disease.²⁴ Feline tooth resorption has been shown to start as focal lesions at the cemento-enamel junction, indicating that local factors appear to play a role in the etiopathogenesis.²⁸ Feline tooth resorption has an initial resorptive phase where there is odontoclastic resorption of dentin and destruction of the periodontal ligament and alveolar bone.²⁹ This is followed by cementum and bone deposition during the reparative phase. Thus far, bone deposition and dento-alveolar ankylosis, as described in feline tooth resorption, has not been described in equids. Treatments with long-term antibiotics and steroids have been unsuccessful and extraction of affected incisors has been the only treatment to alleviate the clinical signs associated with this disease.

Canine teeth disorders

The most common abnormality observed in canine teeth is, as noted, the accumulation of calculus, which may cause mild local periodontal disease. This calculus is easily removed with the use of forceps. Excessive calculus accumulation on the mandibular canines has also been associated with corresponding tongue ulcers. Rarely, canine teeth may be displaced or enlarged and interfere with the bit. Canine teeth have very long, well embedded reserve crowns, and extraction of these teeth should not be performed without prior radiography. The canine teeth are often floated, purportedly to prevent biting problems or injuries to operators' hands and arms during dental procedures. Extreme floating or even cutting of these canine teeth may expose the pulp cavity and result in apical infections. Enlargement of the clinical crown, exposure of the alveolar bone or reserve crown, and the presence of pain if the canine is palpated, percussed or subjected to a cold substance (piece of ice), are all indications for radiographic evaluation of the canine.

Cheek teeth disorders

Dental abnormalities of wear encountered in geriatric equids are the same abnormalities that are recognized in younger equids, but they have reached an advanced stage over a prolonged period of time. These disorders, e.g., shear mouth, wave mouth, and focally overgrown teeth, are often complicated by the lack of reserve crown and hence, instability of teeth within the alveolus, which results in displacement and eventually loss of teeth (Fig. 18.10).

A post-mortem survey of dental disease in geriatric donkeys (estimated median age 31 years) showed a very high prevalence (93%) of dental disease; with diastemata (85%), missing (56%), displaced (43%) and worn teeth (34%) being the most common dental disorders present³⁰

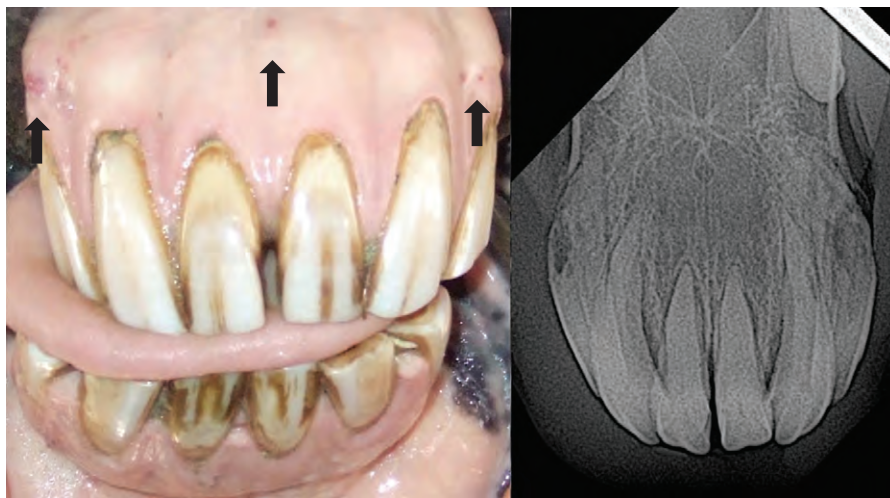


Fig. 18.9 This 20-year-old Thoroughbred was reported to refuse to bite carrots for over one year. Enlargement of all incisor reserve crowns is prominent with gingival recession, and draining tracts visible (at arrows). Radiographs showed extensive lysis and hypercementosis of 103 and 203, typical of equine odontoclastic tooth resorption and hypercementosis, with radiographic changes in all the other incisors.

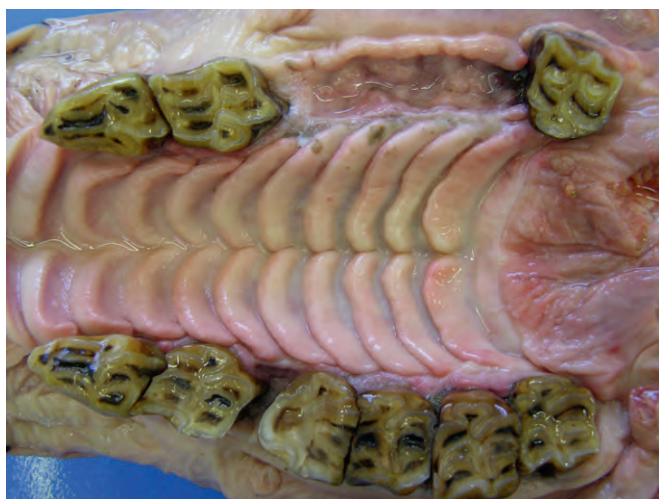


Fig. 18.10 Loss of maxillary cheek teeth 208, 209, and 210 is due to loss of reserve crown in this geriatric donkey. Also note the large, open diastema between 107 and 108 and the loss of infundibular enamel in 108, indicating the presence of a high degree of wear in these teeth and the beginning of 'smooth mouth'.



Fig. 18.11 Severe bilateral lateral displacement of the 310 and 410 is present in this 38-year-old donkey. There is also moderate lateral displacement of the 407.

(Fig. 18.11). Studies in horses have also shown an increased prevalence of dental disease in older age groups.^{1,2,31-33} A comparison of clinical dental disorders in different age groups of donkeys (age range 2–53) showed a significant increase in the prevalence of dental disease in donkeys over 20 years of age ($\geq 88\%$ prevalence) compared to donkeys younger than 20 years ($\leq 64\%$).⁴ More specifically, a significant increase in the prevalence of diastemata, missing teeth, overgrown teeth, worn teeth, displaced teeth, and periodontal disease with increasing age has been shown, in particular in donkeys over 20 years of age.⁴ As expected, the prevalence of enamel points decreased significantly with age, to a prevalence of less than 20% in donkeys older than 20 years, as compared to $>40\%$ prevalence in donkeys under 20 years of age.⁴

Treatments of cheek teeth disorders in geriatric equids are often limited by the lack of reserve crown. Dental treatment should be aimed at preserving as much of the functional occlusal surface for mastication as possible, while ensuring

oral comfort. Sharp enamel overgrowths should be floated to prevent soft tissue trauma to the cheeks (maxillary cheek teeth) or tongue (mandibular cheek teeth). Cheek teeth diastemata are often a result of tapering reserve crowns and loss of angulation of the rostral and caudal cheek teeth ('senile diastemata'), and, therefore, the cause of these diastemata cannot be eliminated (Fig. 18.12). As diastemata often involve the caudal cheek teeth,^{30,34} it is essential that a dental mirror and good light source are used to evaluate these. Impacted food should be flushed out, and the severity of associated periodontal disease determined. Very often, the only treatment for diastemata is to reduce the opposing cheek teeth occlusal surface by 2–3 mm to decrease the impaction of food into the diastema, particularly if there are focal transverse overgrowths secondary to the diastemata.³⁴ Some clinicians advise filling the base of cleaned diastemata with dental impression material (as later described), but no objective studies are available on its efficacy in treating any type of periodontal disease in the horse. Following removal of cheek teeth overgrowths, mild-to-moderate periodontal

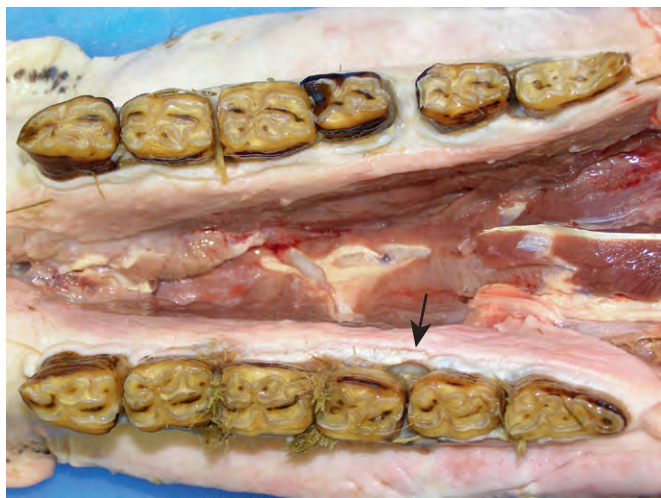


Fig. 18.12 Multiple senile diastemata of both mandibular cheek teeth rows in a donkey of 27 years. Some of these diastemata have adjacent severe periodontitis and deep periodontal pockets (arrow).



Fig. 18.13 Slight wave mouth with overgrowths of 410 and 411 and moderate peripheral caries. Diastemata are present in all the interdental spaces in this cheek teeth row, but the diastema between 408/409 has severe periodontal disease and food pocketing associated with it.



Fig. 18.14 Calculus accumulation on the buccal aspect of 207 and 208 in a geriatric (33-year-old) donkey. There is also a diastema with food impaction and periodontal pocketing between 208 and 209, and displacements of 209 and 210 (arrow).



Fig. 18.15 Severely overgrown maxillary cheek tooth resulting in 'step mouth'. This overgrown tooth needs to be reduced in stages to prevent potential pulp exposure. Also note the associated periodontal disease and gingival recession.

disease may be arrested or its progression slowed by oral rinsing with diluted chlorhexidine gluconate (5 ml of 2% chlorhexidine added to one liter of water). The owner should rinse the mouth out once a day for 10 days, then twice weekly. Some horses object to the taste of chlorhexidine and may become briefly anorectic. If this occurs, a flavored 0.12% chlorhexidine (or human mouthwash) can be used as a rinse, 50 to 100 ml per rinse. The mouth should be rinsed with lukewarm water to remove food particles prior to the chlorhexidine rinsing.

Periodontal disease is an important disease in geriatric equids and has been shown to occur in 80% of horses over 20 years of age² (Fig. 18.13). If the periodontal disease is severe and associated with periodontal pockets, the application of an antibiotic oral gel (Doxirobe [doxycycline] Gel, Pfizer Animal Health) with impression material may allow temporary alleviation of the inflammation and allow healing of the periodontal pocket.^{35,36} In contrast to small animals

where the accumulation of calculus is an important cause of periodontal disease,³⁷ cheek teeth calculus is less common in equids and is not a major cause of periodontal disease. Cheek teeth calculus accumulation has been observed in 19% of geriatric donkeys at post mortem, predominantly on the maxillary 07, 08, and 09 cheek teeth³⁰ (Fig. 18.14). Cheek teeth calculus often accumulates secondary to food stagnation in equids that have painful dental disease and subsequent decreased normal masticatory movements. These teeth are beside the salivary duct opening that possibly provides much of the mineral component for calculus.

Excessive cheek teeth overgrowths resulting in 'step mouth' should be reduced as much as possible (Fig. 18.15). If overgrowths are more than a few mm high, the initial reduction should be done in stages (e.g., 3 mm at a time) at 2–3-month intervals to prevent potential pulp horn exposure. As these overgrowths are secondary to missing, displaced, or 'cupped out' teeth in the opposing cheek teeth row,

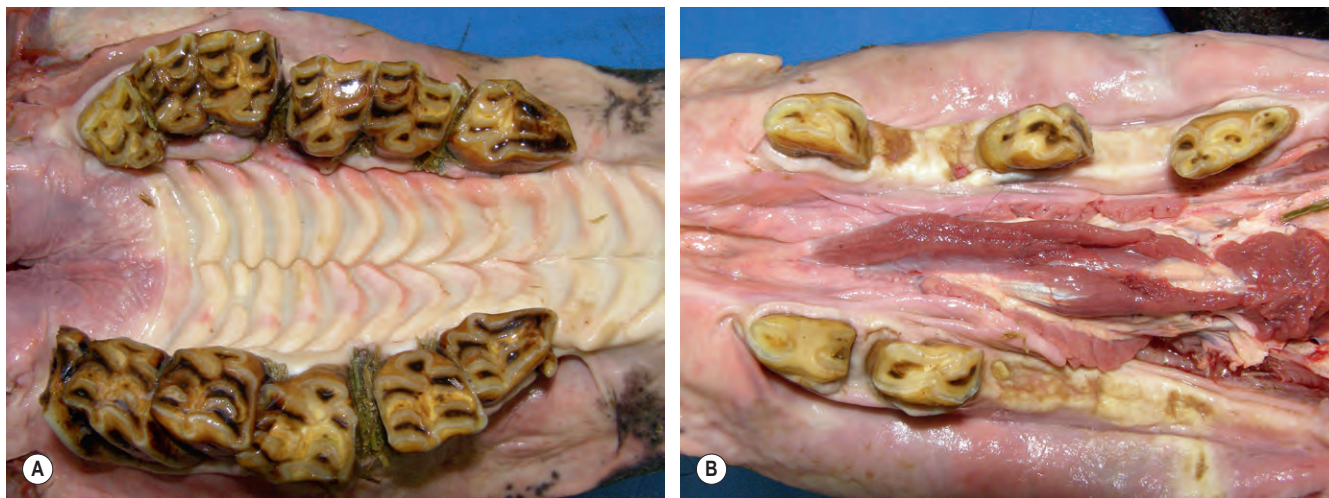


Fig. 18.16 Corresponding maxillary (A) and mandibular (B) cheek teeth rows that illustrate severely overgrown maxillary cheek teeth secondary to worn and missing mandibular cheek teeth, with mandibular soft tissue trauma. There are also multiple maxillary cheek teeth diastemata with food impaction. Note the presence of the rudimentary 205 (first premolar, wolf tooth).

treatment needs to be repeated at regular intervals, to prevent re-development of these overgrowths to an extent that they are interfering with masticatory movements or causing soft tissue damage. These overgrowths do not have to be fully reduced (Fig. 18.16). Severely displaced teeth should be extracted if they are protruding into the cheeks or tongue and causing chronic ulceration and pain. Mild to moderately displaced teeth with focal overgrowths on the displaced and opposing teeth due to the malocclusion can be managed by reducing the overgrowths if the teeth are not digitally loose. Overgrown, slightly loose teeth may re-attach firmly if overgrowths are removed. However, if teeth are very loose or have marked periodontal disease and diastemata, extraction is the most appropriate treatment. Oral extraction of displaced teeth, particularly if still well embedded in the alveolus, may be complicated by the limited space between the cheek and tooth and the inability to satisfactorily apply molar extractors. Therefore, careful consideration must be given to the potential duration of the procedure and the required sedation to a debilitated geriatric equid.

Wave mouth is believed to develop as a result of the oldest teeth in the mouth (09s) wearing and becoming 'cupped out' prior to younger adjacent teeth, thus causing uneven wear in a cheek teeth row (Fig. 18.17).³⁸ Treatment of wave mouth consists of floating excessively overgrown teeth to theoretically create a straight (or slightly concave) occlusal surface in the cheek teeth rows in a rostrocaudal direction, in mild cases. However, in the usually more severe cases of wave mouth, only the area of maximal overgrowth can be reduced without removal of very significant amounts of the reserve crown. The aim is to create maximal occlusal contact surface area and allow for the normal range of mandibular jaw movement for efficient mastication. The cheek teeth row must not be floated to the height of worn teeth, but rather the overgrowth on the opposing tooth should be floated. When reducing overgrown cheek teeth, it is important to remember the normal occlusal angle of mandibular (18–31°) and maxillary (12–9°) cheek teeth in a lingual-buccal and buccal-palatal direction, respectively.³⁹



Fig. 18.17 'Wave mouth' in a right mandibular cheek teeth row with a medially displaced 408 and 406, an overgrown 410, and worn 411. A large diastema between 407 and 408 with periodontal disease and gingival recession is also present, as is moderate peripheral caries of the 406 and 407, most likely secondary to food stagnation due to abnormal masticatory action.

Other abnormalities of wear may result in further malocclusions, with geriatric equids usually presented with multiple dental disorders. Prolonged overgrowths of the 106, 206, 311 and 411 may result in restricted rostrocaudal movement and contribute to more pronounced generalized cheek teeth overgrowths.

Ultimately, most geriatric equids with dental disease need to have regular (6-monthly or annually) dental examinations and treatment as appropriate on welfare grounds to ensure oral comfort and masticatory efficiency. It is highly likely that those with significant dental wear or disease will require supplemental feeding to maintain a suitable body weight, and this is particularly so in the colder months when green forage is not available. Owners need to be educated on the long-term management of geriatric equids, with particular emphasis on the formulation of an appropriate diet.

References

- Baker GJ. Some aspects of equine dental disease. *Equine Vet J* 1970; 2: 105–110
- Wafa NS. A study of dental disease in the horse. MVM Thesis, University College Dublin, Dublin, 1988
- Kirkland KD, Marretta SM, Inoue OJ, Baker GJ. Survey of equine dental disease and associated oral pathology. *Proceedings of the 40th American Association of Equine Practitioners Annual Convention* 1994; 40: 119–120
- du Toit N, Burden FA, Dixon PM. Clinical dental examinations of 357 donkeys in the UK: Part 1 – Prevalence of dental disorders. *Equine Vet J* 2009; 41(4): 390–394(5)
- Uhlinger C. Survey of selected dental abnormalities in 233 horses. *Proceedings of the 33rd American Association of Equine Practitioners Annual Convention* 1987; 33: 577–583
- Brosnahan MM, Paradis MR. Demographic and clinical characteristics of geriatric horses: 467 cases (1989–1999). *Journal of American Veterinary Medical Association* 2003; 223: 93–98
- Hillyer MH, Taylor FRG, Mair TS, et al. Diagnosis of hyperadrenocorticism in the horse. *Equine Veterinary Education* 1992; 18: 131–134
- Dybdal N. Pituitary pars intermedia dysfunction (equine Cushing's-like disease). In: Robinson NE, ed. *Current therapy in equine medicine*. WB Saunders, Philadelphia, 1997, pp 499–501
- du Toit N, Burden FA, Dixon PM. Clinical dental examinations of 357 donkeys in the UK: Part 2 – Epidemiological studies on possible relationship between different dental disorders, and between dental disease and systemic disorders, 2009; 41: 395–400
- du Toit N, Gallagher J, Burden FA, Dixon PM. Post mortem survey of dental disorders in 349 donkeys from an aged population (2005–2006): Part 2 – Epidemiological studies. *Equine Vet J* 2008; 40: 209–213
- Dixon PM, Copeland AN. The radiological appearance of mandibular cheek teeth in ponies of different ages. *Equine Veterinary Education* 1993; 5: 317–323
- Misk NA, Seilem SM. Radiographic studies on the development of cheek teeth in donkeys. *Equine Practice* 1999; 19: 27–37
- Dixon PM. The gross, histological, and ultrastructural anatomy of equine teeth and their relationship to disease. In: *Proceedings of the 48th American Association of Equine Practitioners Annual Convention* 2002; 421–437
- Dixon PM, Dacre I. A review of equine dental disorders. *Equine Vet Educ* 2005; 169: 165–187
- Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease part 2: a long-term study of 400 cases: disorders of development and eruption and variations in position of the cheek teeth. *Equine Vet J* 1999; 31: 519–528
- Ralston SL, Squires EL, Nockels CF. Digestion in the aged horse. *Equine Veterinary Science* 1989; 9: 203–295
- Ralston SL, Breuer LH. Field evaluation of a feed formulated for geriatric horses. *Equine Veterinary Science* 1996; 16: 334–338
- Pugh DG. Feeding the geriatric horse. In: *Proceedings of the 53th American Association of Equine Practitioners Annual Convention*, Orlando, Florida, 2007, pp 193–195
- Donaldson LL. Anesthetic considerations for the geriatric equine. In: Bertone JJ, eds. *Equine geriatric medicine and surgery*. Elsevier, St Louis, 2006, pp 25–37
- Goodrich LR, Clark-Price S, Ludders J. How to attain effective and consistent sedation for standing procedures in the horse using constant rate infusion, In: *Proceedings of the 50th American Association of Equine Practitioners Annual Convention*, 2004, pp 229–232
- Carmalt JL. Safety, restraint, and oral examination of the horse. In: AAEP Dental focus meeting, Indianapolis, Indiana, 2006
- Rucker BA. Utilising cheek teeth angle of occlusion to determine length of incisor shortening. *Proceedings of the 48th American Association of Equine Practitioners Annual Convention*, 2002, pp 448–452
- Collison M. Food processing and digestibility in horses. B Sc dissertation. Monash University, Victoria, 1994
- Gregory RC, Fehr J, Bryant J. Chronic incisor periodontal disease with cemental hyperplasia and hypoplasia in horses. In: AAEP Dental focus meeting, Indianapolis, Indiana, 2006
- Baratt RM. Equine resorptive lesions. In: *Conference proceedings of the 21st Annual Veterinary Dental Forum*, Minneapolis, 2007, pp 123–130
- Caldwell LA. Clinical features of chronic disease of the anterior dentition in horses. In: *Conference proceedings of the 21st Annual Dental Forum*, Minneapolis, 2007
- Stazyk C, Bienert A, Kreutzer R, et al. Equine odondoclastic tooth resorption and hypercementosis. *The Veterinary Journal* 2008; 178: 372–379
- DeLaurier A, Boyde A, Horton MA, Price S. A scanning electron microscopy study of idiopathic external tooth resorption in the cat. *Journal of Periodontology* 2005; 76: 1106–1112
- Gorrel C. Feline odontoclastic resorptive lesions. In: *World Small Animal Veterinary Association 23rd World Congress Proceedings*, Bangkok, Thailand, 2003
- du Toit N, Gallagher J, Burden FA, Dixon PM. Post mortem survey of dental disorders in 349 donkeys from an aged population (2005–2006). Part 1: prevalence of specific dental disorders. *Equine Vet J* 2008; 40: 204–208
- Honma K, Yamakawa M, Yamauchi S, Hosoya S. Statistical study on the occurrence of dental caries of domestic animal: I. Horse. *Japanese Journal of Veterinary Research* 1962; 10: 31–36
- Miles AEW, Grigson C. *Coyler's variations and diseases of the teeth of animals*, Cambridge University Press, Cambridge, 1990, p. 672
- Uhlinger C. Common abnormalities of the premolars and molars. *Proceedings of the 37th American Association of Equine Practitioners Annual Convention* 1991; 37: 123–128
- Dixon PM, Barakzai S, Collins N, Yates J. Treatment of equine cheek teeth by mechanical widening of diastemata in 60 horses (2000–2006). *Equine Vet J* 2008; 40: 22–28
- Green SK, Basile T. Recognition and treatment of equine periodontal disease. *Proceedings of the 48th American Association of Equine Practitioners Annual Convention* 2002; 48: 463–466
- Klugh DO. Equine periodontal disease. *Clinical Techniques in Equine Practice* 2005; 4: 135–147
- Wiggs RB, Lobprise HB. Periodontology. In: Wiggs RB, Lobprise HB, eds. *Veterinary dentistry: Principles & practice*, Lippincott-Raven Publishers, Philadelphia, 1997, pp 186–231
- Leue, G. Zähne. In: Dobberstein J, Pallaske G, Stunzi H, eds. *Handbuch der speziellen pathologischen anatomie der haustiere*, 3rd edn. Verlag Paul Parey, Berlin, 1941
- Brown S, Arkins S, Shaw DJ, Dixon PM. The occlusal angles of cheek teeth in normal horses and horses with dental disease. *Veterinary Record* 2008; 162: 807–810

Basic equine orthodontics and maxillofacial surgery

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Basic equine orthodontics

Introduction

The prevention of and treatment for dental malocclusions is the field of dentistry known as orthodontics. Orthodontics, in its most basic form, is the controlled movement of teeth through alveolar bone. The purpose of equine orthodontics is to correct or prevent irregularities and malocclusions of the teeth and/or jaws through equilibration of dental crowns, application of dental appliances, exodontia, and/or surgery.

The orthodontic principles of tooth movement are at work on horses that develop abnormal wear patterns on exposed dental crowns. Dental elongations place stresses on the tooth that can result in abnormal movement. The general laws of biomechanics apply to movement of teeth. Alveolar bone is reabsorbed when the root and reserve crown maintain compressive force on the periodontal ligament. New alveolar bone is deposited when stretching forces act on bone. However, these laws are subject to numerous variations and exceptions when factors such as magnitude, direction, and duration of force are introduced.¹ Dental cementum has the inherent tendency to resorb when pressure is applied to it but to a lesser degree than bone. Dental floating and equilibration are forms of orthodontic correction used in an attempt to reduce abnormal forces placed on teeth and thus improve occlusion. The application of orthodontic wire, springs, coils, arch bars, bands, brackets, incline planes, and elastics has been used in correcting common malocclusion problems of horses (Fig. 19.1).²⁻⁵

Extracting deciduous teeth to guide the eruption of the permanent teeth into a favorable occlusion has been referred to as preventative or interceptive orthodontics.⁶ Interceptive orthodontics, when wisely and judiciously applied to well-selected cases, can prevent dental malocclusions that cause functional problems with dental wear throughout the horse's life (Fig. 19.2).

Many dental malocclusions involve an abnormal skeletal relationship between the upper and lower jaws. General form and capacity for growth of bone are inherited

characteristics. A basic understanding of the growth of the upper and lower portions of the head is important in the diagnosis and treatment for many types of malocclusions⁷ (see Ch. 5).

Bone is plastic, and its form and capacity for growth are affected and modified by environmental forces and factors. A branch of orthodontic treatment, first referred to as biomechanical orthodontics, has developed over the past century. Applying the theories of bone plasticity traced back to Fouz and Wolff, several techniques have been used to correct dentofacial deformities and malocclusions in the horse using the principles of functional orthodontics.⁸ A more descriptive term, functional jaw orthopedics, was popularized by Karl Haupl, who refined the concepts and techniques used today in this branch of human dentistry.⁹ Pressure, whether functional or artificially created, affects bone growth. Cellular growth of bone is constant, occurring in the young horse from an increase in size and change in form or in the adult from the replacement of dead cells. Bone metabolism remains constant whether forces acting on the bone are normal or abnormal in direction or amount, but bone grows in the direction of least resistance. Forces of occlusion, when acting incorrectly, therefore, become factors of malocclusion.

Functional orthodontics is the use of appliances, devices, or techniques to modify the forces placed on the jaws of young, growing animals to encourage growth in a way that corrects or at least limits the extent of malocclusion when the animal reaches adulthood. Reduction of hooks and elongated teeth that interfere with normal jaw growth is the simplest application of functional orthodontics in horses. Both fixed and removable appliances have been used in foals, with mixed results, in an attempt to modify jaw growth and the spatial relationship between the dental arches (Figs 19.3 & 19.4).

Surgical correction of dental malocclusion and dentofacial deformities in the horse has had limited application. The most severe types of deformities, such as wry nose, have been corrected successfully in a small number of horses by following the principles of orthognathic surgery.¹⁰⁻¹³



Fig. 19.1 (A) Orthodontic spring device used to spread 307 and 309 to allow room for an impacted 308 to erupt. (B) Intra-oral mirror used to visualize the orthodontic spring in the 308 position. (C) Lateral radiograph of impacted 308 with orthodontic spring in the dental space. (Courtesy of B.W. Fletcher DVM.)



Fig. 19.2 Crowded lower incisor arch with retained deciduous teeth 701 and 801, causing displacement (labiocclusion) of permanent teeth 301 and 401. Following the principles of interceptive orthodontics, the deciduous teeth were removed, and the exposed mesial crown portions of 702 and 802 were filed, widening the space for 301 and 401 to migrate forward.



Fig. 19.4 Removable functional orthodontic mouthpiece on a 10-month-old gelding. This device incorporated a metal incline plane and a restrictive band labial to the upper incisors. This type of device works well, but owner compliance with long term care, is a problem.



Fig. 19.3 Removable functional orthodontic device in the mouth of a 5-month-old foal with a parrot-mouth deformity. This device is used to improve the dental alignment and encourage growth of the lower jaw. The device must be worn 16 hours daily and requires intensive nutritional management and husbandry of the foal for a successful outcome.

Osteodistraction surgical techniques have been employed to correct both wry nose and parrot mouth.¹⁴

Malocclusion can be categorized according to three etiological types:

1. congenital or genetic malocclusion
2. eruptive malocclusion
3. traumatic malocclusion.

Most horses with reasonable dentofacial alignment and occlusion and normal jaw function, should be considered to have normal occlusion. Although a very small abnormality in occlusal contact can affect dental wear, its impact on function cannot always be predicted by its morphology. Understanding the concepts of normal occlusion is fundamental to orthodontic diagnosis. (See Ch. 6, Dental physiology.)

The equine veterinary literature has given little attention to any type of dental malocclusion with the exception of parrot mouth. Although parrot mouth is probably the most common malocclusion of the incisors, many other types of dental malocclusions of the horse are more commonly encountered. Many types of malocclusion occur in horses.¹⁵ Colyer (1935) and Joest (1970) described many variations seen in equine teeth that lead to various types of dental malocclusion.^{16,17} Hypsodont teeth that are not properly aligned in the dental arcade suffer from severe abnormalities of wear. Abnormal wear has been shown to be the leading cause of dental disease and to adversely affect proper mastication.¹⁸

Surveys of equine dental patients have shown a high percentage of horses with significant dental malocclusions.^{15,19–22} Many of these malocclusions were severe enough to cause clinical problems, and a certain percentage of affected horses were classified as having a handicapping unsoundness.¹⁵ Treatment of horses with a dental malocclusion has been aimed at correcting dental overgrowth and managing periodontal disease.^{18,21,23,24} Orthodontic techniques have been introduced by equine practitioners to correct some of the more severe dental malocclusions.^{25,26} Dentofacial deformities, such as wry nose, parrot mouth, and monkey mouth, involve both the dental complex and the facial skeleton.

The genetic and functional environment work closely to determine the growth of all bones.^{27,28} The genetic factors that are at play and the veterinary literature pertaining to craniofacial deformity in domestic animals have been reviewed.²⁹ The intrauterine environment has a known effect on facial growth and development. Intrauterine molding occurs when growth of the fetus is greater than that of the uterus, causing pressure from the uterus to distort the developing face. Intrauterine molding has been documented to occur in human beings and may be the cause of some facial and skeletal limb deformities seen in foals.^{30,31} Postnatal environmental factors affecting morphology include all non-genetic influences brought to bear on the developing individual. These include the environmental effects of muscle function and neuromuscular adaptation.^{32,33} Force placed on the teeth and jaws of the growing horse from abnormal wear of the exposed dental crowns is another factor to consider.

The scientific basis of environmental causes of malocclusion rests primarily on findings of experiments performed on animals.²⁷ Under certain experimental conditions, growth can be extensively stimulated or stunted. The duration of pressure has a greater effect on growth than does the magnitude. Environmental factors that are recognized as leading to dentofacial abnormalities include:

- habits of long duration, such as sucking
- posture of the head, mandible, tongue, and lip because posture determines the resting pressure on soft-tissue
- eruption of the tooth and wear of the crown
- trauma, either osseous, soft tissue, articular, or dental.

The current theory for explaining growth of the craniofacial bones states that growth of the face occurs in response to functional needs and is mediated by the soft tissue in which the jaw is embedded.³⁴ That is, the soft tissues grow, and both the bone and cartilage follow this growth.

Function plays an important role in normal growth of the jaw and is closely related to inherited patterns of growth.

Perturbation of growth of the jaw can be induced by trauma to the soft tissues.²⁷ In response to the disturbance of optimal occlusal relationships, growth of the jaw can be modified by a new functional environment. To modify inherited growth of the jaw of human beings, the functional disturbance must be of sufficient magnitude and duration (e.g., more than 6 hours per day for thumb-sucking by children).⁹ Deviation of the mandible to one side causing dental malocclusion is common in tethered pigs and is probably due to the pig pulling on its tether in one direction to reach food and water³⁵ (Fig. 19.5).

Epidemiological studies are needed to establish breed or family predisposition to malocclusion. The classification system of malocclusion (i.e., modified angle) presently being used in human and small animal dentistry is not well adapted for use in the horse.^{6,36,37} Such a classification system of malocclusion does not exist for horses even though we use the MAL Class 1–3 system adapted by the AVDC.³⁸ A well-designed system and its standardized use by a broad base of well-informed observers would be helpful in acquiring meaningful information about the effect of treatment in horses suffering from dental malocclusion. Additionally, cephalometric measurements and studies of jaw interrelation during craniofacial growth in the horse are essential for orthodontic therapy of horses to progress.

Sequelae of malocclusion

Malocclusion of the continually erupting and wearing hypsodont teeth of horses leads to abnormal wear patterns of the exposed dental crowns. Mechanical forces placed on teeth that are wearing abnormally can cause teeth to move within their alveolus. The teeth may tip, rotate, or shift, depending on the angle of force applied, leading to formation of diastemata (i.e., periodontal pocketing), the leading cause of periodontal disease.^{39,40} Most malocclusions cause teeth to wear in such a fashion that abnormal forces are applied to the teeth and jaws, exacerbating malocclusion. These abnormally worn teeth alter the masticatory pattern of some horses. They can also lead to secondary abnormalities of wear, such as alteration of the angle of the molar tables and inadequate wear of the buccal edges of the upper arcades and lingual edges of the lower arcades. The most severe form of this type of altered wear pattern is referred to as shear mouth.

Examples of altered wear causing tooth movement

Long enamel points and exaggerated transverse ridges may form due to malalignment of the upper and lower jaws. Exaggerated transverse ridges wedge between the teeth in the opposite arcade, forcing the teeth apart to create diastemata into which food becomes packed. Misplaced teeth develop abnormal wear of their occlusal surface with the unopposed portion of the crown becoming protuberant and developing an excessive angle. Mechanical forces placed on the protuberant crown force the tooth further out of alignment and can cause tipping or increased malalignment of the crown, which leads to periodontal packing of feed around the displaced crown. The tooth in the opposing arcade does not wear normally and may become protuberant or develop



Fig. 19.5 (A) Foal developed unilateral hypoglossal nerve paralysis 24 hours after birth. The tongue can be seen protruding out of the left side of the mouth. (B) Same foal at 5 months of age. The tongue protrudes from the left side of the mouth except when it is stimulated. (C) The incisor teeth no longer meet on the left side due to ventral deviation of the rostral mandible from constant tongue pressure. This foal regained full function of the tongue by 10 months of age, but retained a diagonal incisor arcade.



Fig. 19.6 Prominent hooks on 106 and 206 due to malocclusion of the upper and lower dental arcades. The rostral pressure placed on the 106 has moved it forward causing a space or diastema between 106 and 107 (arrow). This condition can lead to severe periodontal disease and eventual tooth loss.

excessive enamel points or ridges that mirror the defect in the opposite arcade.

A missing or displaced tooth in one dental arcade leads to abnormal wear of the opposing teeth. The mesial and distal teeth in the same arcade tend to drift into the space that is unoccupied. This abnormal interproximal drifting can open spaces between adjacent teeth in the same dental arch, leading to formation of diastemata and periodontal pocketing between teeth and inspiring sequential drifting.^{41,42} This is not a consistent feature, and sometimes all the teeth in the dental arch move simultaneously to close the gap. This closure shortens the dental arcade and predisposes dentition to abnormal patterns of wear (e.g., hooks) on the ends of the opposite arcade. Some drifted teeth become angled medially or laterally so that the side of the crown develops occlusal wear. These angled teeth can have a smooth occlusal surface and excessive attrition of the crown, often associated with a step or wave in the opposing arcade.

Formation of a hook on the rostral aspect of the first cheek tooth (Triadan 06) or caudal aspect of the last cheek tooth (Triadan 11) places force on the crown of the tooth with the protuberance, forcing that tooth away from the rest of the arcade, resulting in a diastema. Packing of feed into the diastema leads to periodontal disease, which if left uncontrolled, may lead to formation of an abscess, loosening of the tooth, and eventually expulsion of the tooth (Fig. 19.6). A rostral or caudal hook can also result in mechanical forces applied to the jaw that affect growth, mastication, shedding of deciduous teeth, head carriage, and function of the temporomandibular joint. As the protuberant portion of the crown at the end of the dental arcade becomes more prominent, it tends to limit rostrocaudal motion of the jaw and place mechanical forces on both the upper and lower jaws. A hook on the first upper or lower cheek tooth of the growing foal works mechanically to restrict the growth of the shorter jaw. In the adolescent horse with mixed dentition, mechanical forces placed on the jaws and teeth from hooks inhibit growth of the shorter jaw and compress the crowns of the

deciduous teeth, limiting the space for the deciduous teeth to shed and predisposing erupting permanent teeth to impaction. In the adult horse, hook formation can lead to several pathological processes depending on the size, shape and position of the hook and the demands for performance placed on the horse.

The position of the jaw changes slightly as the horse moves its head up and down. With the head elevated, the lower jaw retracts caudally in relation to the upper jaw. This can be demonstrated by elevating the head high in the air and noticing the occlusion of the incisor teeth. The cheek tooth arcades also shift with head position. Some clinicians speculate that this positional shifting is the reason that horses that eat from an elevated hay rack or net have a higher incidence of hooks on the rostral aspect of the 06s than do horses that eat in the normal position off the ground.

As a horse flexes its neck, the lower jaw tends to move forward in relation to the upper jaw.⁴³ This becomes important when dealing with horses that are asked to perform with the neck flexed in collection, such as dressage horses, gaited horses, or harness horses worked in an overcheck with their necks forced into flexion. Hooks on the rostral aspect of the upper 06s or caudal aspect of the lower 11s inhibit the rostral motion of the lower jaw when the horse's mouth is closed. Some horses tend to open their mouths when collected, but often, trainers use various types of nosebands to force the mouth closed, thus preventing relief from the forces placed on the jaws and limiting the amount of flexion the horse can exhibit. Secondary problems, such as soreness in one or both temporomandibular regions or in the muscles of the neck or back, can be associated with the horse's inability to freely move its jaw rostrally and caudally.

Documentation of malocclusion and craniofacial deformities

The clinician should document the history and clinical findings of all horses that may require any type of orthodontic treatment. A complete history, including the horse's pedigree and an oral examination of its parents, is helpful in counseling the client about the heritability of the malocclusion. Historical information also allows the clinician to determine whether the condition was noticed at birth or soon after and if it is becoming progressively worse as the horse grows. The proposed use of the horse and knowledge of the rules of its breed's registry are necessary to make ethical decisions regarding treatment of the horse when the deformity may have a hereditary component.

The clinical assessment should begin with a general physical examination of the horse and a complete, detailed, oral examination. Photographs and skull measurements are useful in monitoring clinical progress. Radiographic evaluation of the skull sometimes allows for more precise assessment of the problem and is another source of permanent, measurable documentation for monitoring improvement. Dental impressions and stone castings are helpful in the documentation of deformities as well as in planning treatment. Stone castings can also be used in the fabrication and fitting of removable or fixed dental appliances (see Ch. 21). Bite impressions using a sheet of base plate wax allow for proper alignment of upper and lower stone models and for following progress of treatment.⁶

Parrot mouth

An overjet of the incisor teeth is seen in most mammals, including man. This condition is abnormal in the horse and commonly referred to as parrot mouth, brachygnathism, overshot maxilla, or buck tooth, but officially is classified as a type 2 malocclusion (MAL2). When this malocclusion is slight, the labial aspect of the lower incisors rests on the lingual aspect of the uppers. When the condition is more severe, the incisors are completely out of occlusion, and the premaxillae tend to be deviated downward causing the lower incisors to rest on the hard palate caudal to the upper incisors. The parrot mouth syndrome in horses can involve the incisor portion of the dentition alone, or it can occur in combination with varying degrees of malocclusion of the upper and lower cheek teeth. The mismatch in length of the upper and lower jaws can be either from brachygnathism of the mandible or from prognathism of the maxillae and premaxillae.¹⁷

Mandibular brachygnathism has been reported to occur with other types of congenital deformity involving the musculoskeletal system.^{44,45} Without cephalometric norms, determining whether an affected horse has a short lower jaw or a long upper jaw is impossible. Some observations of horses with parrot mouth show that the lower jaw is shorter (by 1.5–9.3%), while others show that the upper jaw is longer (by 11.15–18.1%).¹⁷ Some observers conclude that the lower jaw of some horses with parrot mouth is underdeveloped.^{16,46} It is not unusual for the upper canines of adult male horses affected with severe parrot mouth to be positioned rostral to the lower canines.

Cattle inspected for breeding soundness show an incidence of parrot mouth ranging from 2–13%. This percentage is similar to the 2–5% incidence of parrot mouth reported in several equine studies.^{15,47} The degree to which this condition is expressed at birth, and the progression of the condition throughout growth and development of the horse have not been scientifically documented. The parrot mouth condition can be acquired by avulsion injury to the incisor teeth or premaxillae, compression fracture of the mandible, or illness immediately prior to a growth spurt.^{48,49}

Equine parrot mouth is most often a result of breeding two horses with normal dental occlusion but extremely different head types. The degree of malocclusion seems to depend on many factors. Some horses are only affected in the region of the cheek teeth, some are affected only in the region of the incisors, and some are affected in both areas. Because horses have hypsodont teeth that depend on normal occlusal contact for wear, horses suffering from parrot mouth are more seriously affected by the condition at all stages in life than are similarly affected members of other species with brachyodont teeth.

Few foals are born with the full expression of parrot mouth (Fig. 19.7). Foals born with a slight incisor overjet (i.e., upper incisor arcade labial to the lower incisor arcade) soon develop an overbite (i.e., the occlusal surface of the upper incisor arcade is dropped ventral to the occlusal surface of the lower incisor arcade). As the upper incisors elongate, the palate and incisive bones are pulled downward by gravity, causing the lower incisors to become trapped as they begin to contact the palate behind the upper incisors (Fig. 19.8).

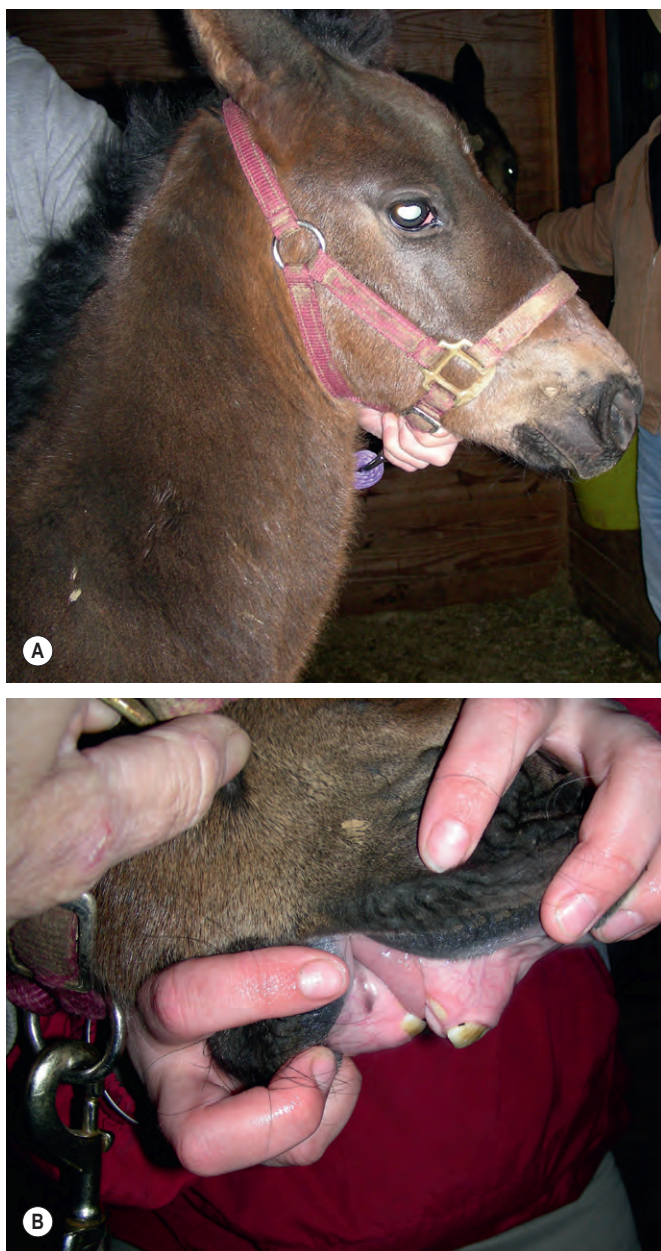


Fig. 19.7 (A) Lateral view of newborn foal with an incisor overjet (parrot mouth). (B) Intra-oral view of foal showing incisor overjet. Only the central deciduous incisors have erupted.

This places caudal pressure on the mandible, inhibiting its growth and creating a cascade of events that worsen the deformity. As the growth of the lower jaw is stunted, the cheek teeth malocclusion worsens, causing hooks to form on the rostral aspect of the upper first cheek teeth (Triadan 506 and 606). The unopposed incisor teeth continue to erupt and elongate. The elongated, unopposed lower incisors trapped between the wider, upper incisor arcade interfere with the normal masticatory cycle and limit free lateral motion of the jaw, leading to more abnormal wear of the cheek teeth.

When advising an owner about managing a horse with parrot mouth, one should keep in mind that the mode of inheritance of malocclusion is not clear. Parrot mouth is a complex conformational trait and is the outcome of

multiple genes (polygenetic). Each breeding horse has a different propensity to pass the deformity on to its offspring. Breeding a horse that has a congenital defect, or breeding a horse that has previously produced offspring with a congenital defect is risky. The breeder's long-term goals and philosophy should dictate breeding decisions. One should consider the horse's good traits and the seriousness of the defect. Breeding horses with any type of congenital defect probably increases the incidence of that defect in the breeding population and may eventually lead to an intolerable concentration of affected horses in the gene pool. An extreme approach would be to neuter horses with congenital defects and to remove their sires and dams from the breeding population. Although this would prevent horses with a congenital defect from passing it on, it would also prevent them from reproducing their good conformational and behavioral traits, and ability to perform. One good strategy would be to not re-mate two horses that have previously produced defective offspring. Another approach would be to re-mate these horses but to retain in the breeding program only offspring that do not exhibit the defect. A good breeding practice is to mate horses with similar virtues but different faults.

Orthodontic management of a horse with parrot mouth should follow four basic principles:

1. abnormal wear of the teeth should be prevented or reduced
2. downward, gravitational drift of the premaxillae and upper incisor teeth should be prevented or corrected
3. rostral growth of the maxillae and premaxillae should be inhibited, and
4. rostral growth of the mandible should be stimulated.

The most important management tool used to correct parrot mouth is to reduce or prevent abnormal dental wear because abnormal dental wear patterns inhibit rostral and lateral movement and growth of the mandible. Rostral hooks on the upper 06s and caudal ramps or hooks on the last lower cheek teeth (08s, 09, 10s, or 11s, depending on the horse's age) should be reduced. Excessive transverse ridges and enamel points on the cheek teeth should be reduced, and vaulted ceiling of occlusion corrected. Incisors excessively long from lack of wear should be reduced to bring the lower incisors out of contact with the soft tissues of the palate and to allow free lateral motion of the mandible. Care must be taken to not expose pulp chambers or to damage teeth when reducing crowns.

Foals with minor overjet (i.e., less than 5 mm) and with no overbite or malocclusion of the cheek teeth benefit from wiring of the upper teeth.^{25,26} This technique is used to inhibit rostral growth of the upper jaw from the second cheek tooth rostrally while allowing the growth of the mandible to proceed unimpeded. This wiring technique used alone is biomechanically unsound for use in horses with overbite or malocclusion of the cheek teeth.

Horses with a more severe malocclusion of the incisors (i.e., overbite) have been improved or corrected by applying a functional, orthodontic device early in their life, when they are in a rapid stage of growth.⁴ Orthognathic surgery and osteodistraction of a few foals has been attempted.¹⁴ Foals born with no contact between the upper and lower incisor teeth have an incisor overjet but no overbite, but within 3–6 months, gravity and soft-tissue tension on the upper lip

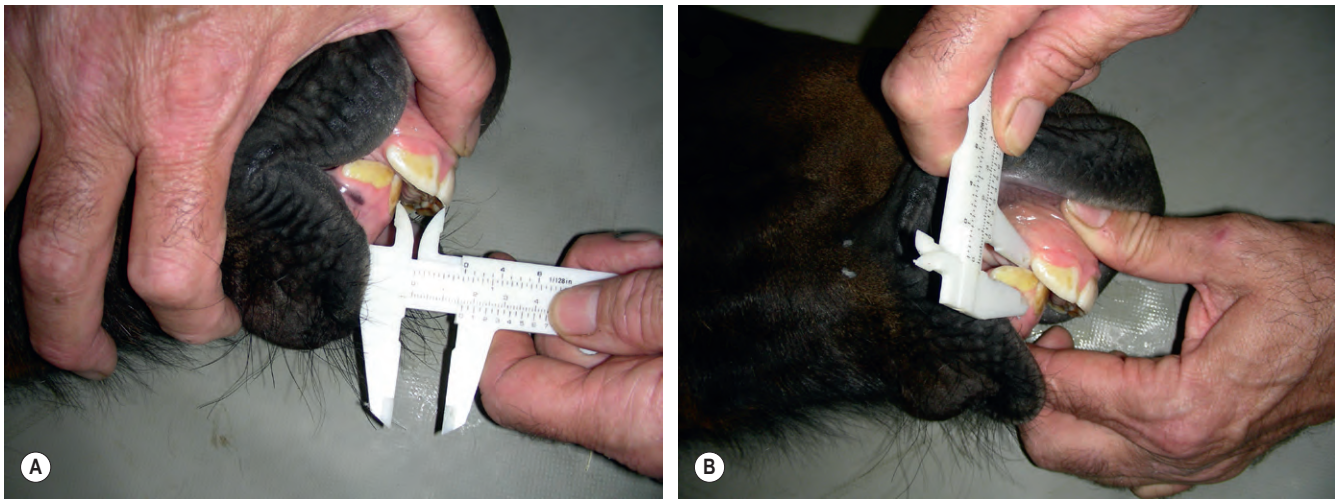


Fig. 19.8 (A) Measuring a parrot-mouth foal's overjet in millimeters. (B) Measuring the overbite in millimeters.

cause the premaxillae and incisive bones to tip downward. This downward curve is evident during oral examination as a bow in the palate midway between the cheek teeth and the incisors. This downward movement of the upper incisors, in combination with lack of attrition or wear, leads to an overbite. Removable or fixed, functional, orthodontic devices combined with retention wires can be used to correct the overbite and allow free movement and rostral growth of the mandible.

Tension band wires have been used to inhibit rostral growth of the upper jaw of foals less than 6 months old that have sufficient potential for growth of the lower jaw to correct the deformity. Stainless steel wire (18- to 20-gauge, AISI 316L) can be used as a tension band device. A wire placed caudal to each second upper cheek tooth and brought rostrally around the upper incisors inhibits growth of this portion of the upper jaw. The lower jaw continues to grow normally, correcting the overjet.

If no portion of the upper and lower incisor arcades is in contact, a combination of tension band wires and a functional orthodontic device is used. Such a device in the most simple form consists of a removable plate, attached to a bit, that extends rostrally between the incisor arcades. When the mouth is closed, the plate places upward pressure on the upper incisors discouraging their ventral drift. A removable orthodontic device can be applied with the foal standing and unsedated. Because the device must be worn 16 hours per day to be effective, owner compliance is the most common problem associated with the use of the removable appliance, and compliance of the foal is the second limiting factor. Without an educated, enthusiastic, and committed owner and/or groom, the use of a removable appliance is doomed to failure.

A more sophisticated, fixed acrylic appliance can be fashioned to fit in the roof of the mouth. Acrylic is molded on a plaster model of the upper jaw or fashioned on the anesthetized foal in dorsal recumbency. A metal inclined plane can be incorporated in this device to place rostral force on the lower jaw when the mouth is closed. Application of these devices cannot be 'cook-booked' because each case presents a slightly different set of anatomical and biomechanical

situations that requires detailed evaluation and careful planning.⁵

The primary advantage of a fixed dental appliance is that it can be permanently attached in the mouth, making compliance by the owner and by the foal less of a factor in success of treatment. To apply a fixed appliance, however, the foal must be anesthetized, and special equipment is required. Because foals grow rapidly, and because they tend to put their mouths in and on things that can damage fixed devices, repair and reapplication of the appliance are all too frequent occurrences. Fixed acrylic appliances that incorporate an aluminum or stainless steel incline plate can be attached to orthodontic retention wires.

The earlier correction is initiated, the better the results. Treatment is best initiated when the intermediate upper incisors (Triadan 502 and 602) are in wear (i.e., when the foal is 6–12 weeks old) so that interference with the eruption of these teeth is avoided. Prior to orthodontic correction, a full set of skull radiographs and occlusive measurements should be obtained. The cheek teeth should be floated to reduce tall transverse ridges and rostral or caudal hooks. The incisor plate opens the bite, thus separating the occlusal contact between the upper and lower cheek teeth. 'Overfloating' of the occlusal surface, therefore, is discouraged because it results in loss of contact between the upper and lower arcades during mastication when the incline plate is in place. Primiparous mares and dams with small nipples on the udder can present a problem for foals attempting to nurse after surgery. Foals should be fed a diet consisting of a pelleted complete foal ration before and after surgery.

Preoperatively, the foal receives antimicrobial and non-steroidal anti-inflammatory drugs, and the mouth is rinsed completely with a dilute chlorhexidine solution. General anesthesia is induced with xylazine and ketamine and maintained with a triple drip (i.e., a combination of xylazine, ketamine, and guaifenesin). The foal is positioned in lateral recumbency, and an oxygen tube is inserted nasally. Oxygen is delivered at 10 l/min during the procedure. Using a rasp or power grinder, the exposed crowns of the upper and lower incisors are reduced and leveled almost to the gingival margin, taking care not to expose the pulp (Fig. 19.9).



Fig. 19.9 Power grinder being used to level and shorten the incisors (3 mm) prior to surgery.

A small area just ventral to the facial crest is clipped and prepared for surgery. With one hand in the mouth, the junction between upper 3rd and 4th premolars (Triadan 07 and 08) on the arcade is identified as an indentation in the hard palate. A small, longitudinal, skin incision is made below the facial crest at a level just opposite this junction, avoiding branches of the facial nerve, maxillary artery, and salivary duct. A $\frac{3}{32}$ -inch diameter Steinmann pin is introduced through the skin incision and directed between the reserve crowns of upper 3rd and 4th premolars just above the buccal gingival margin so that the pin emerges in the mouth $\frac{1}{8}$ – $\frac{1}{4}$ inch above the palatal gingival margin. Care should be taken to avoid the palatine artery. Intra-operative radiographs and/or fluoroscopy are helpful and sometimes necessary to properly position the pin between the teeth without damaging dental roots. The pin is removed, and a 14-gauge, 1.5-inch hypodermic needle is carefully placed in the hole created by the pin to act as a wire guide. A section of 18-gauge, stainless steel, orthopedic wire is cut to a length at least three times the distance from 4th premolar to the central incisors. One end of the wire is inserted into the dorsal aspect of the oral cavity through the needle, and the needle is removed over the other end of the wire, which is then doubled back and passed through the buccal incision into the buccal space of the oral cavity (Fig. 19.10). Care should be taken not to catch soft tissue with the wire or to damage a branch of the facial nerve during this process. The end of the wire in the buccal space is grasped with forceps inserted into the mouth, and it and the palatal portion of the wire are pulled rostrally to form a loop around the distal aspect of the reserve crowns of the upper 2nd and 3rd premolars. Kinks should be avoided because they hasten stress fatigue of the wires. The small skin incision is left open to heal by second intention. The foal is repositioned in lateral recumbency on the opposite side, and the procedure is repeated.

With both wire loops extending out of the oral cavity, the foal is placed in dorsal recumbency with a pad placed caudal to the poll to hyperextend the neck so that the roof of the mouth lies parallel to the ground. The loop wire around the first two cheek teeth is pulled tight and twisted several times



Fig. 19.10 Parrot-mouthed foal in lateral recumbency for placement of orthodontic wires. A Steinmann pin is used to make a hole between the reserve crowns of 607 and 608, and a 14-gauge needle is placed in the hole and used as a guide for the 18-gauge, orthopedic retention wire. The needle is pulled over the free end of the wire. A longer free end of the wire is placed back through the same skin incision just below the facial crest, pushed through the mucosa into the buccal recess and brought rostrally.

on itself in the interdental space. Including the occlusal surface of the upper 2nd premolar in the twists is avoided by keeping the wire close to the hard palate and pulling downward on the buccal wire and upward on the palatal wire while twisting. The twisted strands from both sides are pulled rostrally and brought around the labial edge of the upper incisor arcade and twisted together. The wires should lie across the labial surface of the incisors at the gingival margin. The ends of the wires are cut and tucked between two incisors. An $\frac{1}{8}$ -inch-thick plate of aluminum with several 3.5 mm perforations is sized so that it fits over the occlusal surface of the upper incisors and extends caudally over the hard palate $\frac{1}{4}$ inch caudal to the point at which the lower incisors contact the hard palate (Fig. 19.11A). Paraffin rope is placed around the gingival margin of the upper incisors, pulled under the wires on each side, and extended several centimeters caudally on the hard palate to form a dental dam to contain the unset acrylic (Fig. 19.11B). Hard-setting dental acrylic is mixed and formed into the roof of the mouth, within the confines of the paraffin rope, incorporating the wires and labial surface of the upper incisors. The acrylic should cover the knot in the wire on the labial aspect of the upper incisors to prevent the knot from irritating soft tissue. Splinting of the upper incisor arcade with acrylic stabilizes the teeth and prevents the force of the orthodontic wires from spreading or twisting the incisors. The acrylic band wrapping around the labial surface of the upper incisors and the orthodontic wires hold the acrylic firmly in the roof of the mouth. The acrylic is formed with the curved, rostral edge of the metal plate resting on the occlusal surface of the upper incisors and the caudal, straight edge of the plate level or slightly more ventral in the mouth than its rostral edge. This creates a flat or inclined surface for the lower incisors to contact (Fig. 19.11C). This inclined plate frees the mandible from caudal force imposed on it by the upper incisors and creates a slight rostral pull on the



Fig. 19.11 (A) Parrot-mouthed foal placed in dorsal recumbency with orthodontic retention wires in place. An aluminum plate is cut and sized to fit the occlusal surface of the upper incisors while projecting caudally to contact the occlusal surface of the lower incisor arcade. A dam of paraffin rope has been built to retain the acrylic mouth piece. (B) Acrylic and thin plate in place. (C) Lateral view showing final placement of wires and acrylic mouth piece.

mandible as the lower incisors slide over the plate during chewing. As the foal chews, upward pressure is applied to the upper incisors and premaxillae, forcing them into a more normal position (Fig. 19.12).

The foal is allowed to recover from anesthesia after the acrylic sets and is returned to the dam. Most foals quickly learn to nurse with the appliance in place. Foals that do not nurse well should be supplemented with a complete foal ration and weaned.

Postoperative care consists of keeping the skin wounds clean until healing is complete. Most foals are administered omeprazole orally for 4–5 days, while they adjust to the orthodontic appliance, to help prevent gastric ulcers. Most foals begin to eat and nurse well within 1–2 days after surgery. The plate and wires should be checked daily by personnel at the farm to determine if the wires are loose or broken or if the acrylic appliance has loosened. The foal should be examined monthly by a veterinarian to ensure that the appliance is secure and is not causing oral lesions. At the same time, the cheek teeth should be inspected so that abnormal wear patterns can be detected and corrected by careful floating.

The appliance eventually loosens, so that by 3–6 months the appliance and wires must be removed. If correction is not complete by this time, the wires and acrylic appliance are reapplied and maintained until desirable results are achieved. The gap between the upper and lower incisors decreases, for most horses, by about 5 mm every 3–6 months. The most rapid correction is noticed when the procedure is performed when the horse is 2–8 months old; improvement is slow after the horse is 8 months old and ceases by the time the horse is 19 months old. Complications from orthodontic wiring and bite plate application are rare. They can include trauma to the dorsal buccal nerve, damage to the greater palatine artery, postoperative pain and nursing problems, and nasal curvature from unilateral wire breakage.⁵⁰

Adult horses suffering from parrot mouth experience long-term adverse effects on dentition and mastication. The molar arcades may develop a hook on the rostral aspect of the upper 06s and/or a hook and/or ramp on the caudal aspect of the lower 11s, and the cheek teeth of both the upper and lower jaws may develop abnormal, exaggerated transverse ridges. The combination of abnormalities of the cheek teeth and elongated incisors tends to limit free, lateral excursion

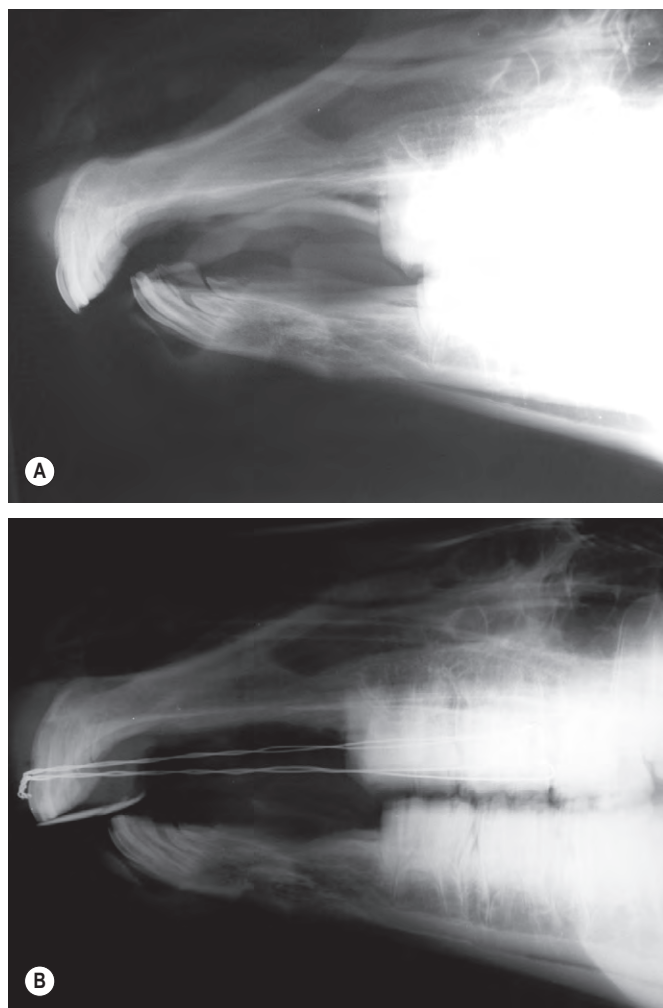


Fig. 19.12 (A) Lateral radiograph of the rostral skull of a 4-month-old foal with an overjet and overbite just prior to surgery (B) Lateral skull radiograph of foal with orthodontic retention wires placed behind the upper third premolar and encircling the upper incisor arcade. The metal incline plate has not been sloped for this first application of retention wires because creating a slope would have caused a gap in the premolar arcades. The second appliance will have a slope or mechanical incline to encourage rostral growth of the mandible.

of the jaw, which can lead to a steep angle of the occlusal surface of the cheek teeth or, in some cases, to bilateral shear mouth.

Some parrot-mouthed horses function quite well if they receive regular dental equilibration and if their diet is modified. Dental equilibration entails reduction of rostral and caudal hooks, abnormal exaggerated transverse ridges, and steep molar angles. Unopposed upper and lower incisor arcades should be shortened to allow more normal, unobstructed motion of the lower jaw. Deciduous incisors can be shortened with little risk of damaging the pulp chambers. Permanent incisors, especially long ones, should be reduced in stages.

In addition to having its teeth equilibrated, a parrot-mouthed horse should also have its diet altered or modified. Some parrot-mouthed horses have difficulty foraging short grass; others have difficulty masticating any type of roughage, and so, to maintain these horses in good body condition, feeding processed or extruded feeds may be beneficial.



Fig. 19.13 Four-week-old foal with a monkey mouth or Mal 3 deformity.

Monkey mouth

The term monkey mouth refers to the condition where the premaxillae/maxillae are shorter than the mandible, leading to an incisor underbite. This condition has also been termed sow mouth, hog mouth, undershot jaw, underjet, underbite, or mandibular prognathism, but the official term is a Class 3 malocclusion (MAL3). Retrognathism is a term defined, using human anatomical nomenclature, as a condition where the mandible is located posterior to its normal position in relation to the premaxillae/maxillae or a condition where one or both jaws lie posterior to normal in their craniofacial relationship.

The forward projection of one or both jaws in relation to the craniofacial skeleton has been referred to as prognathism. This condition is seen more commonly in miniature horses and has been associated with achondroplastic dwarfism in cattle.^{51–53} Prognathism is also seen in other breeds of horses, especially those with a dished face, such as the Arabian breed. This congenital anomaly has been reported to occur with other deformities of the head and musculoskeletal system. Owners should receive genetic counseling before therapy is undertaken to correct monkey mouth (Fig. 19.13).

Principles of therapy in the young, growing horse should consist of:

- encouraging or accelerating growth of the maxillae and premaxillae
- supporting the nasal bones and nasal septum
- slowing rostral growth of the mandible
- preventing the upper incisor arcade from interfering with the lower incisor arcade, and
- preventing abnormal wear of the cheek teeth.

Adult horses with a hook on the rostral aspect of the lower 06s can develop a slightly undershot lower jaw. This abnormality can be corrected by periodically floating the cheek teeth to remove the hooks and by reducing the incisors.

Wry nose

Wry nose, or campylorrhinus lateralis, is a congenital deviation of the maxillae, premaxillae, and nasal septum



Fig. 19.14 (A) Four month old wrinkle nose foal. (B) Dorsoventral radiograph of a wrinkle nose foal. The maxilla is deviated at a 65° angle to the mandible.

(Fig. 19.14). It is an infrequently reported condition sometimes associated with other congenital anomalies, such as cleft soft palate (palatoschisis), umbilical herniation, and contracted tendons of the limb.⁵⁴ Affected foals may have difficulty suckling, but most seem to thrive until dyspnea appears when they are several months old. The degree of dyspnea is related to the severity of the nasal septal deviation. Severely affected foals may require a permanent tracheostomy or a nasal dilation tube to ventilate properly. Horses affected with wrinkle nose usually encounter difficulty prehending and masticating grass forage when they are weaned. Lateral excursion of the lower jaw is usually limited to movement to the convex side of the deformity, causing abnormal wearing of cheek teeth, which may lead to shear mouth.

Wrinkle nose is thought by some to be a heritable condition because it seems to be seen most often in the Arabian and miniature horse breeds,^{52–54} but these claims are not

supported by scientific evidence. The authors are aware of a mare that produced two foals affected with wrinkle nose, during successive pregnancies, when bred to the same stallion (Dr Chris Johnson, personal communication, 2008).

Mildly affected foals have been managed using unilateral orthodontic wiring with good results. More severely affected foals have been treated successfully using principles of orthognathic surgery, as detailed later in this chapter, and many of these treated foals have developed into successful athletes and productive breeders.^{11,13,55,56}

Foals should be evaluated carefully for aspiration pneumonia and to rule out associated congenital defects. The degree of the deformity can be determined by oral radiographic examination, and computed tomography of the skull might be useful to confirm the position and degree of premaxillary/maxillary deviation and nasal obstruction (Fig. 19.15). Dental impressions of the upper and lower arcades from the premolars to the incisors can help the surgeon determine the amount of space created on the concave side of the premaxillae/maxillae when the deformity is corrected and the upper and lower incisor arcades are brought into proper occlusion (Fig. 19.16). Occlusal abnormalities of the premolars causing wear should be corrected prior to surgery. This involves re-establishing a normal occlusal angle on the premolar arcades and leveling the incisors (Fig. 19.17).

Conclusion

All undesirable traits and pathologic conditions present at birth were at one time thought to be entirely genetic in origin. Our knowledge of birth defects has evolved to the point that we now know that many, if not most, congenital defects are the result of intrauterine events that result from extrauterine influences. Congenital defects do not indicate inheritance but simply that the defect was present at birth.

Some characteristics of horses are genetically influenced, and horses have been selectively bred for centuries to promote or discourage these characteristics. The selection for or against inherited tendencies is the basis for our current breed registries. Size, power, color, speed, conformation, and many other characteristics that are genetically influenced, are selected for or against by certain breed registries. Variations from ideal may be undesirable, but they are not genetic defects.

The American Veterinary Medical Association (AVMA) recently restated a policy saying that surgical correction of 'genetic defects' for the purposes of concealing the defect is unethical.⁵⁷ This AVMA statement refers specifically to correction of genetic defects. By definition, a genetic defect is a pathologic condition of proven genetic origin.

Although equine practitioners should support the intent of the AVMA statement, the policy should be applied only to horses with a genetic defect and not misapplied to horses with a congenital defect for which a genetic cause has not been proven or to horses with inherited tendencies. Equine practitioners should consider surgical treatment of horses with a debilitating condition if the condition is amendable by surgical correction. There is no doubt that correction of debilitating dental malocclusions and facial deformities is in the best, long-term interest of the horse's oral health. Some equine breed registries require certain undesirable traits and/

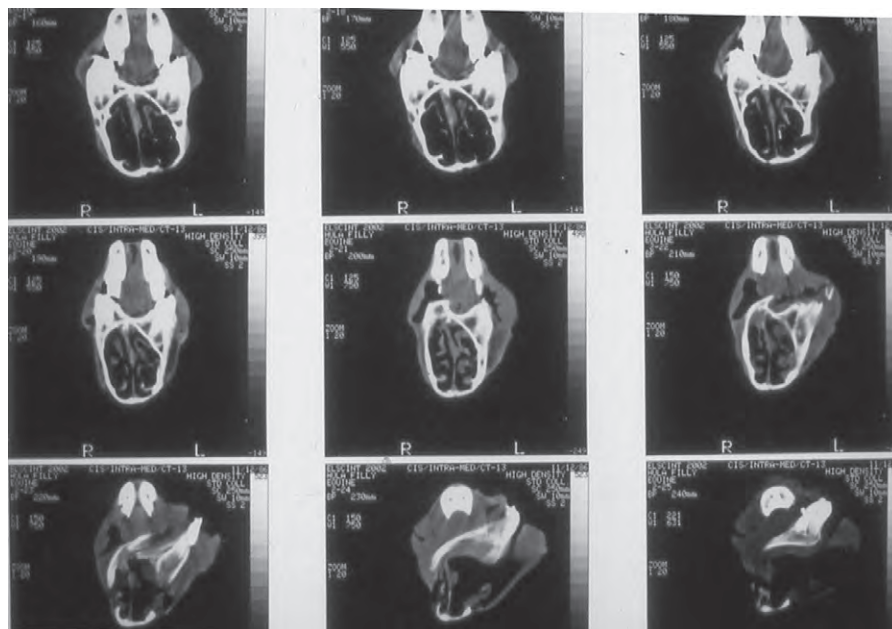


Fig. 19.15 Computed tomography images of transverse scans through the head of a 7-month-old Thoroughbred filly with wry nose. The filly is positioned in dorsal recumbency, and serial images, beginning at the second premolar and advancing rostrally, demonstrate the premaxillary curvature and progressive narrowing of the right nasal cavity.



Fig. 19.16 Plaster of Paris dental model of the upper arcade from a wry-nosed foal. The model has been cut and straightened to bring the upper and lower incisor arcade into proper occlusion. The white wedge indicates the angle of rostral and lateral displacement required to correct the deformity.

or conditions commonly considered to be a 'genetic defect' to be indicated on the affected horse's registration certificate. This requirement should be brought to the attention of an owner or breeder when a severe malocclusion is diagnosed. An attempt to correct a known genetic defect to allow an owner to misrepresent the horse in the show ring or breeding shed should be considered unethical.

Clinical observation and detailed documentation promote understanding of why and how malocclusions and malrelationships between the jaws occur and how they can be prevented or treated. The equine practitioner can benefit greatly from the new human biomedical discoveries. Genetic studies to detect the chromosomal factors that play a role in head shape could influence genetic consultation and mating engineering. Such studies and/or research may help reduce the incidence of equine dental malocclusions.

Equine orthodontic principles are at work in the mouth starting in utero and continuing well into old age. Changes occur as the deciduous teeth erupt, the jaws grow and develop, deciduous teeth are shed, permanent dentition erupts, and the hypsodont teeth wear. The equine practitioner who is familiar with the principles of diagnosis and documentation of malocclusion is better able to use the controlled movement of teeth and adjustments of jaw growth for treatment. Knowledge obtained through observation, diagnosis, documentation, and appropriate adjustments provides the equine dental patient with the best possible occlusion and helps maintain proper oral health.

Surgery of the paranasal sinuses

Sinusotomy

Surgery of the paranasal sinuses is performed most commonly to determine the cause of clinical signs of disease referable to the paranasal sinuses, such as facial deformity or chronic, unilateral nasal charge. It is also performed to excise or biopsy abnormal tissue, such as an osteoma, cyst, progressive ethmoidal hematoma, fungal granuloma, or neoplasm, or to evacuate inspissated exudate, usually from the ventral conchal sinus. It is sometimes performed to expose the apex of a diseased tooth so that the tooth can be repulsed into the oral cavity or receive endodontic treatment. The paranasal sinuses can be exposed through one or more trephine openings or through an osteoplastic flap. Although the paranasal sinuses can be examined endoscopically through one or more trephine holes, treatment of the horse for a disease identified endoscopically is often not possible, unless the trephine opening is huge, in which case the horse may be left with facial deformity. Surgery of the paranasal sinuses is, therefore, usually performed through one or more large osteoplastic flaps that are replaced at the end of surgery.



Fig. 19.17 (A) and (B) Twelve-year-old Thoroughbred mare with a wry nose. A 'permanent' tracheostomy as a yearling allowed the mare to breathe with no signs of respiratory distress. She had produced six normal foals while being bred to six different stallions. The uncorrected dental and facial deformity caused the mare difficulty with prehension and mastication. She had a severe shear mouth on the concave (right) arcades.

The two types of osteoplastic flaps are the frontonasal flap and the maxillary flap. The frontonasal flap is the most versatile because it is easy to create and provides direct or indirect access to all compartments of the ipsilateral paranasal sinuses. The maxillary flap is more difficult than the frontonasal flap to create and provides poor access to the ventral conchal sinus, at least in horses less than 6 years old. The maxillary flap provides good access to the rostral and caudal maxillary sinuses, however, and is most commonly used to expose the apex of the first or second maxillary molar (Triadan 09 and 10). The apex of the third maxillary molar (Triadan 11) is often best exposed through a frontonasal flap. The surgeon should have a good understanding of the

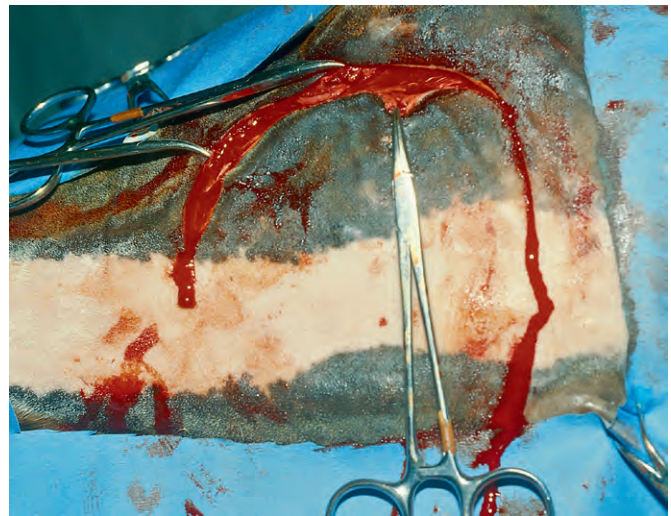


Fig. 19.18 To create a medially hinged, osteoplastic frontonasal flap, a three-sided incision extending through periosteum is created within the confines of the boundaries of the conchofrontal sinus.

boundaries and anatomical features of the paranasal sinuses before performing sinusotomy.

Frontonasal flap

To create a medially-hinged, osteoplastic frontonasal flap, a three-sided incision through the skin, subcutaneous tissue, and periosteum, with rounded corners, is created within the confines of the boundaries of the frontal and dorsal conchal sinuses (i.e., the conchofrontal sinus; Fig. 19.18). The caudal portion of the incision begins on the dorsal midline, at a point midway between the supraorbital foramina and the medial canthi of the eyes, and extends laterally, perpendicular to the long axis of the head, to a point about 1.5–2 cm medial to the most medial aspect of the rim of the orbit. The rostral portion of the incision also begins on the dorsal midline, at a point 1–2 cm caudal to the plane where the nasal bones begin to diverge, and extends laterally, perpendicular to the long axis of the head, to an imaginary line extending from the medial canthus of the eye to the nasoincise notch. The lateral portion of the incision connects the lateral extent of the rostral and caudal portions of the incision and courses parallel to the midline. The incision should not cross the path of the nasolacrimal duct, which courses between the medial canthus of the eye and a point midway between the infraorbital foramen and the nasoincise notch. The rostral aspect of the lateral segment of the incision can be angled medially, if necessary, to avoid crossing the duct. Periosteum is reflected several millimeters from the underlying frontal and nasal bones with a periosteal elevator.

The incision is extended through bone using an oscillating bone saw, a motorized cast cutter with a sharp, oscillating blade, or a mallet and osteotome. The blade of the saw should be cooled with sterile, normal saline solution, while cutting, to avoid overheating bone. The bone is cut at a 45° angle so that the flap's external lamina is slightly larger than its internal lamina. The flap is elevated sufficiently, using a chisel or osteotome, to allow the fingers of one hand to be introduced beneath the flap, and the flap is fractured at its

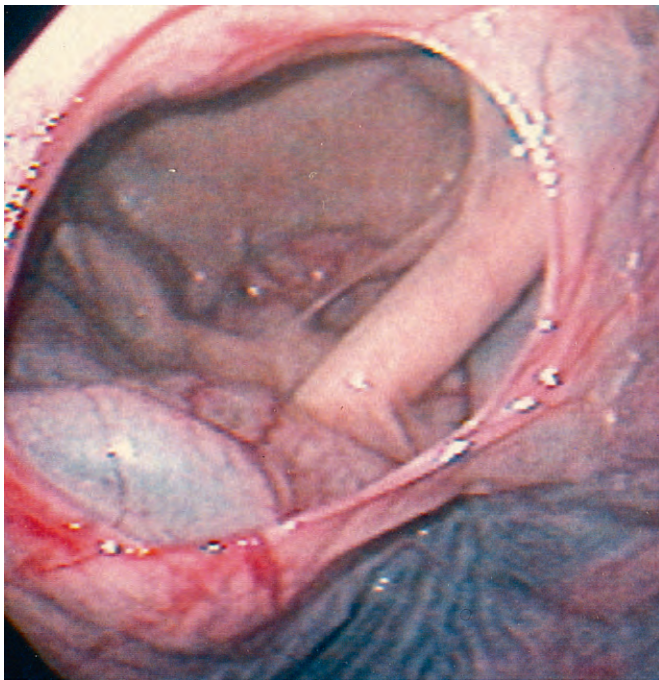


Fig. 19.19 The bulla of the ventral conchal sinus is seen protruding into the caudal maxillary sinus beneath the rostral margin of the frontomaxillary aperture. The bulla structure is sometimes obscured by the caudal portion of the floor of the dorsal conchal sinus.

base, close to the dorsal midline. The flap remains attached to the skull by skin, subcutaneous tissue, and periosteum.

Elevating the flap exposes the conchofrontal sinus, which communicates ventrally with the caudal maxillary sinus through the large frontomaxillary aperture. Provided that the architecture of the sinuses is not distorted by disease, the bulla of the ventral conchal sinus, which forms a portion of the maxillary septum, is usually seen protruding into the caudal maxillary sinus beneath the rostral margin of the frontomaxillary aperture (Fig. 19.19). Occasionally, this structure is obscured by the caudal portion of the floor of the dorsal conchal sinus. To expose the rostral maxillary and ventral conchal sinuses, a portion of this bulla is excised with scissors. After creating a hole in the bulla, the ventral conchal sinus is seen medial to the infraorbital canal, and the rostral maxillary sinus is seen lateral to the canal. The infraorbital canal is supported by a thin plate of bone that separates these two compartments. All or a portion of the reserve crowns of the 3rd, 4th, and 5th cheek teeth (Triadan 08–10) completely fill the rostral maxillary sinus of horses less than 4 years old. To better expose the ventral conchal and rostral maxillary sinuses, the rostrolateral portion of the floor of the conchofrontal sinus and the closely associated dorsolateral portion of the ventral conchal bone can be excised using a scissors or a bone rongeur.

The medial wall of the dorsal or ventral conchal sinus is often perforated, or a portion of it is excised, to establish a portal for drainage of the paranasal sinuses into the nasal cavity, and creating this portal is generally accompanied by substantial hemorrhage. A portal for drainage need not be established if the nasomaxillary aperture is patent, provided that the mucosa of the sinuses is not grossly thickened. Patency of the aperture can sometimes be determined by



Fig. 19.20 A progressive ethmoidal hematoma exposed through a conchofrontal, osteoplastic flap created with the horse sedated.

threading a 5- to 8-Fr, male dog urinary catheter into the caudal opening of the nasomaxillary aperture, located between the floor of the dorsal conchal sinus and the bulla of the ventral conchal sinus at the rostral aspect of the frontomaxillary aperture. The end of the catheter exits the ipsilateral external naris. Threading a catheter through the nasomaxillary aperture can sometime be difficult or even impossible, but blood or lavage fluid seen exiting the nasal cavity can also be used as evidence that the nasomaxillary aperture is patent. Rarely is the nasomaxillary aperture obstructed.

A portal to remove gauze packing or to allow lavage of the sinuses can be created in the frontal bone, adjacent to flap, through a 2-cm, longitudinal, skin and periosteal incision, using a 9.5-mm ($\frac{3}{8}$ -inch) Galt trephine. Alternatively, the portal can be created in the maxillary bone about 2 cm ventral and 2 cm rostral to the medial canthus of the eye.

After returning the flap to its normal position, at the end of surgery, the subcutaneous tissue is apposed with 4–6, widely-spaced, simple interrupted, absorbable sutures. Because the bone in the flap is beveled, it need not be attached to surrounding bone, and suturing the fragile, inelastic periosteum is difficult to impossible. The margins of the skin incision are apposed with staples, and the surgical site is compressed with a Stent bandage or with gauze swabs anchored by elastic, adhesive tape placed in a figure-of-eight fashion around the head. Gauze packed into the sinuses can be removed through the trephine hole, usually within 12 hours, and the Stent or elastic bandage is removed at 5–7 days. The portal created for lavage of the sinuses or to remove the gauze packing can be closed with staples or sutures after the portal is no longer required.

Surgery of the paranasal sinuses is usually performed with the horse anesthetized and recumbent, but most surgeries of the paranasal sinuses that can be performed through a frontonasal flap can also be performed with the horse standing, thereby eliminating the risks and expense of general anesthesia (Fig. 19.20). Repulsion of a tooth, however, is most safely performed with the horse anesthetized. Creating a frontonasal flap causes minimal hemorrhage, regardless of the position of the horse, but performing surgery within the sinuses with the horse standing seems to cause less hemorrhage than surgery performed with the horse anesthetized

and recumbent.⁵⁸ Performing surgery of the horse's sinuses with the horse standing and its head elevated may result in less venous congestion in structures of the paranasal sinuses, and hence less hemorrhage, than if the same surgery were performed with horse recumbent. Another advantage of performing surgery of the sinuses with the horse standing is that the structures within the sinuses are oriented in a normal position.

A horse selected to receive surgery of the sinuses while standing should be compliant and should not resent movement of hands and instruments about its head. When performed with the horse standing, surgery of the paranasal sinuses is most safely and conveniently performed with the horse restrained in stocks; cross-tying the horse's halter to the stocks provides added restraint. The horse is sedated with detomidine HCl (0.01–0.02 mg/kg IV or 0.03–0.04 mg/kg intramuscularly) and butorphanol tartrate (0.02–0.05 mg/kg IV) or morphine (0.15 mg/kg IV). When administered intramuscularly, detomidine should be administered 15–20 minutes before surgery. The horse can be re-sedated during surgery with xylazine (0.5 mg/kg IV) or detomidine (0.01 mg/kg IV), when needed, to minimize movement. If a long procedure is anticipated, constant rate infusion of detomidine (0.02 mg/kg/hour) and butorphanol (0.012 mg/kg/h) can be administered to provide a prolonged, constant state of sedation, after first administering a loading dose of detomidine (0.008 mg/kg IV) and butorphanol (0.02 mg/kg IV).⁵⁹ The horse can also be sedated using constant-rate infusion of morphine (0.15 mg/kg/h) after first administering a loading dose of morphine (0.15 mg/kg IV). After the horse is sedated, its head should be supported on a stand or small table so that the site of sinusotomy is at a comfortable level for the surgeon.

The proposed site of incision is infused subcutaneously with local anesthetic solution, and the paranasal sinuses are desensitized, either by infusing 30–40 ml of local anesthetic solution into the sinuses or by anesthetizing the ipsilateral maxillary nerve. Instilling local anesthetic solution into the paranasal sinuses usually desensitizes the mucosa sufficiently to permit most procedures to be performed without causing severe discomfort to the horse. The local anesthetic solution is infused through a small hole created several centimeters medial to the medial canthus of the eye with a Steinmann pin in a Jacob's chuck or with a steel 14- or 16-gauge hypodermic needle driven through a stab incision in the skin and frontal bone with a mallet. A plug of tissue is often retained within the shaft of the needle and can be extruded into the sinuses with a smaller gauge, spinal needle inserted through the shaft of the larger needle.

The paranasal sinuses can be desensitized more effectively by anesthetizing the maxillary nerve at the pterygopalatine fossa, where it passes through the maxillary foramen to enter the infraorbital canal as the infraorbital nerve. To anesthetize the maxillary nerve, a 20-gauge, 8.9-cm (3.5-inch) spinal needle is inserted just ventral to the zygomatic process at the level of the lateral canthus of the eye, perpendicular to the long axis of the head until the needle strikes bone. Ten-fifteen milliliters of local anesthetic solution is deposited at this site.

The paranasal sinuses can also be desensitized by depositing 10 ml or more of local anesthetic solution into the rostral aspect of the infraorbital canal. This large volume



Fig. 19.21 The infraorbital foramen is located by placing the thumb (or middle finger) in the nasomaxillary notch, and the middle finger (or thumb) on the rostral end of the facial crest. The foramen is located with the index finger halfway between 1.5 and 2.5 cm caudal to an imaginary line between these points.

anesthetizes the infraorbital nerve, which courses through the canal, as far caudally as the maxillary foramen. To locate the infraorbital foramen, the thumb (or middle finger) is placed in the nasomaxillary notch, and the middle finger (or thumb) is placed on the rostral end of the facial crest. The foramen is located with the index finger halfway between and 1.5 to 2.5 cm (0.5–1 inch) caudal to an imaginary line between these points (Fig. 19.21). The bony ridge of the foramen can be palpated by pushing the ventral edge of the levator nasolabialis muscle dorsally. A 20- or 22-gauge, 3.8 cm (1.5 inch) needle is inserted through the skin about 2.5 cm (1 inch) rostral to the foramen after elevating the levator nasolabialis muscle. The shaft of the needle is inserted about 1 inch into the canal. Although anesthetizing the infraorbital nerve is easier and more reliable than anesthetizing the maxillary nerve, the infraorbital nerve block is not tolerated well by the horse, and so great care should be taken during its administration. Anesthesia of the infraorbital nerve or maxillary nerve at the maxillary foramen desensitizes the paranasal sinuses on that side of the head, but desensitization of the skin at the proposed site of incision by subcutaneous infiltration of local anesthetic solution is still required.

After the horse's paranasal sinuses and skin at the proposed site of incision are desensitized, the surgical site is prepared for surgery. The surgical site should not be draped, so that the horse's reactions to the procedure can be monitored. A twitch should be applied to the horse's upper lip when the bone is cut to prevent the horse from moving, but the twitch can usually be removed after the flap is fractured. The paranasal sinuses are inspected, and the horse is treated for disease encountered. If the maxillary nerve was not desensitized with local anesthetic solution before surgery, the horse may react to manipulations within the sinuses, especially if the infraorbital canal is touched with instruments.

An alternative method of exposing the paranasal sinuses with the horse standing is to create a hole into the concho-frontal sinus through a cutaneous, periosteal flap, using a 5-cm (2-inch) diameter trephine (Arnolds Veterinary

Products Ltd, Harlescott, Shrewsbury, UK), as described by Quinn et al (2005).⁶⁰ The site of trephination is centered 5 cm axial to an imaginary line between the medial canthus of the eye and the nasoincisive notch, 2 cm below a line drawn between the medial canthi, and 4 cm lateral to the dorsal midline. Bone of the forehead is exposed through an abaxially based, curved, cutaneous incision created 1–1.5 cm axial to the intended site of trephination. This incision is extended through the periosteum, and the cutaneous, periosteal flap is reflected abaxially. The edge of the trephine is aligned 10 mm inside the skin incision. The disc of bone excised with the trephine is discarded. At the end of surgery, four or five, simple-interrupted, widely-spaced sutures are placed to approximate the skin and periosteum in a single layer, and the skin incision is stapled. Using a large trephine, rather than an oscillating saw, to expose the sinuses simplifies surgery, while still providing adequate exposure for removal of diseased tissue, but removing the large section of bone sometimes imparts a marked concavity to the horse's forehead.

Maxillary osteoplastic flap

The apex of a maxillary molar is often exposed through an osteoplastic maxillary flap. Creating a maxillary flap, rather than a trephine hole, to expose the apex of a maxillary molar provides opportunity for visual examination of a large extent of the paranasal sinuses and permits easier manipulation of dental instruments within the sinuses. The most common indication for creating a maxillary osteoplastic flap is repulsion of a tooth.

To create a dorsally hinged, osteoplastic maxillary flap, a three-sided incision through the skin, subcutis, and periosteum, with rounded corners, is created within the confines of the boundaries of the rostral and caudal maxillary sinuses (Fig. 19.22). The caudal boundary of the maxillary sinuses extends from the middle of the eye to the facial crest, and

the ventral boundary extends along the facial crest to below the middle of the eye. The rostral boundary is a line that extends from the infraorbital foramen to the rostral border of the facial crest, and the dorsal boundary is a line that extends from the medial canthus of the eye to the infraorbital foramen.

The caudal portion of the cutaneous incision begins at a point about 1 cm rostral to the eye, slightly below the medial canthus, and extends ventrally to a point about one centimeter dorsal to the facial crest. The incision is extended rostrally, parallel to the facial crest to a point about one centimeter caudal to the rostral end of the facial crest. The incision is turned dorsally and extended to a point about one centimeter caudal to the infraorbital foramen. The rostral portion of the incision extends into the nasolabialis and levator labii superioris muscles and may transect the angularis oculi artery and vein. Periosteum is reflected about 3 mm to the inside of the three-sided incision, and the maxillary bone is cut along the incision using an oscillating saw or a mallet and an osteotome. The bone is cut at a 45° angle, so that its external lamina is slightly larger than its internal lamina. Care should be taken when cutting the bone at the dorsal, rostral end of the incision to avoid damaging the infraorbital canal and the infraorbital nerve contained within. After the rostral, caudal, and ventral sides of the flap have been cut, the flap is pried upward until it fractures dorsally to expose the interior of the rostral and caudal maxillary sinuses. Septal attachments on the interior surface of the bone flap sometimes must be severed with the osteotome before the flap can be pried dorsally. The flap is hinged dorsally by skin, subcutis, and periosteum. Besides repelling a tooth through a maxillary flap, inspissated exudate in the ventral conchal sinus can also be removed through a portal into this compartment created below the infraorbital canal, provided that the horse is more than 6 years old (Fig. 19.23). The sagittal bony plate beneath the



Fig. 19.22 To create a dorsally hinged, maxillary flap, a three-sided incision extending through the periosteum is created within the confines of the boundaries of the rostral and caudal maxillary sinuses.



Fig. 19.23 Inspissated exudate in the ventral conchal sinus can also be removed, through a portal in the sagittal bony plate and the lateral wall of the ventral conchal sinus located beneath the infraorbital canal, provided that the horse is older than 6 years. The reserve crowns of the first and second maxillary molars of horses less than 6 years old obscure this bony plate and lateral wall of the sinus. VCS, ventral conchal sinus; RMS, rostral maxillary sinus; IOC, infraorbital canal.

infraorbital canal and the lateral wall of the ventral conchal sinus are penetrated using a small trephine or a bone rongeur. The reserve crowns of the first and second maxillary molars of horses less than 6 years old obscure this bony plate and lateral wall of the sinus. The ventral conchal sinus can be exposed by deforming the conchomaxillary aperture, located medial to the infraorbital canal, with a finger.⁶¹ The ventral conchal sinus of horses less than 6 years old is most easily penetrated at its bulla, which is exposed through a fronto-nasal, osteoplastic flap. Inspissated exudate in the ventral conchal sinus most commonly results from primary bacterial sinusitis, but it can also accompany sinusitis secondary to dental infection.

If the sinuses require lavage after maxillary sinusotomy, the portal for lavage can be created over the frontal bone into the conchofrontal sinus or through the maxillary bone into the caudal maxillary sinus, caudal to the flap, about 1.5 cm ventral to the most ventral aspect of the orbit. Packing the paranasal sinuses to achieve hemostasis after repelling a tooth is seldom, if ever, necessary. A trephine portal large enough to accommodate a 24 Fr Foley catheter is created into the conchofrontal sinus through a 3- or 4-cm longitudinal cutaneous incision created over the frontal bone, 2–3 cm medial to the medial canthus of the eye. Fluid instilled into the conchofrontal sinus through the Foley catheter exits the sinuses into the nasal cavity through the nasomaxillary aperture.

After returning the flap to its normal position, after the tooth has been repelled, the subcutaneous tissue is apposed with 4–6, widely spaced, simple interrupted, absorbable sutures. Attaching the flap of bone to surrounding bone is not necessary, because the flap is beveled. Only the subcutis and skin are sutured, because the inelastic periosteum is difficult to appose. The cutaneous margins of the flap are apposed with staples, and the surgical site is compressed with a Stent bandage or with gauze swabs anchored by elastic, adhesive tape placed in a figure-of-eight fashion around the head. The Stent or elastic bandage is removed at 5–7 days. The portal created for lavage of the sinuses can be closed with staples or sutures after the portal is no longer required.

Partial mandibulectomy

The most common indication for partial mandibulectomy is to remove a neoplastic lesion of the rostral aspect of the mandible. The most commonly encountered mandibular neoplasm is the juvenile ossifying fibroma, and this neoplasm is most commonly found on the mentum (Fig. 19.24). Consequently, the mentum is that portion of the mandible that is most frequently amputated. Other neoplasms sometimes encountered on the mentum include the carcinoma (Fig. 19.25) and ameloblastoma. Another indication for amputation of the rostral aspect of the mandible is fracture of the mentum not amenable to repair.

The rostral portion of the mandible can be amputated with the horse anesthetized and in dorsal recumbency or with the horse sedated using local or regional anesthesia to desensitize the mentum. The horse should receive an antimicrobial and an anti-inflammatory drug prior to surgery. If the procedure is performed with the horse anesthetized



Fig. 19.24 The juvenile ossifying fibroma is the most commonly encountered mandibular neoplasm and is most commonly found on the mentum.



Fig. 19.25 Laterolateral radiograph of the skull of a horse with a carcinoma of the mandible. The rostral portion of the mandible of this horse was amputated caudal to the symphysis.

using gas anesthesia, the endotracheal tube should be inserted into the trachea through a nasal cavity so that the oral cavity is maximally exposed. Administering a bilateral mental nerve block after the horse is anesthetized allows the horse to be maintained at a lighter depth of anesthesia. To perform the surgery with the horse standing, the mandibular alveolar nerves are desensitized by injecting local anesthetic solution through a needle inserted through the mental foramen into the mandibular canals. If deformity of the mentum from disease makes inserting a needle into the canals difficult, the mentum can be desensitized by infusing the submucosa around the site at which the mandible is to be amputated with local anesthetic solution.

The horse's mouth is maintained in an opened position with a wedge speculum inserted between the cheek teeth, and the rostral aspect of the mandible prepared for surgery. The gingiva is incised horizontally at the ventral margin of the abnormal bone, and the incision is extended through the periosteum. Each end of the incision is directed dorsally to the center of the right and left interalveolar spaces. At the dorsal aspect of the horizontal ramus of each hemimandible, each end of the incision is redirected rostrally to the corner incisor and then medially until the ends of the incision meet on the midline caudal to the central incisors. The mucoperiosteal flaps created are reflected 15–20 mm beyond the margin of the abnormal bone using a curved, periosteal elevator.

The mandible is transected caudal to the lesion but rostral to the caudal margin of the symphysis using an oscillating saw or obstetrical wire (Figs 19.26 & 19.27). If necessary, hemorrhage from the mandibular stump can be ameliorated by applying bone wax to the cut edge of the bone. Sharp edges of bone are smoothed with a rongeur. The submucosa and periosteum of the lingual flap are apposed to the submucosa and periosteum of the labial flap, using 2-0 or 0-absorbable suture in a simple-continuous or cruciate suture pattern, and the mucosal margins of the flaps are apposed with simple-interrupted, cruciate, or vertical mattress sutures using the same suture material (Fig. 19.28). Inserting a Penrose drain into the space between the two flaps through a stab incision created on the ventral aspect of the mentum prevents formation of a hematoma between the two flaps. Phenylbutazone should be administered twice daily for at least several days after surgery to provide analgesia.

The appearance of a horse that has had the rostral aspect of its mandible amputated in this fashion is nearly normal, but the procedure imparts slight flaccidity of the lower lip (Fig. 19.29). Horses are able to prehend grain and grass normally.⁶² Initially, the tongue may protrude intermittently between the lips.

If a portion of the symphysis is left intact, the need for internal fixation of the mandibles is avoided, but if

the rostral portion of the mandible must be amputated caudal to the symphysis, fixing the right and left hemimandibles to each other may be necessary, using a spacer, such as a portion of rib, at the site of amputation to maintain the proper relationship of the dentition of each hemimandible to its opposing maxillary dentition. However, one of us (JS) amputated the rostral portion of a horse's mandible caudal to the symphysis, without fixing the hemimandibles to each other, and this horse suffered no postoperative complications.

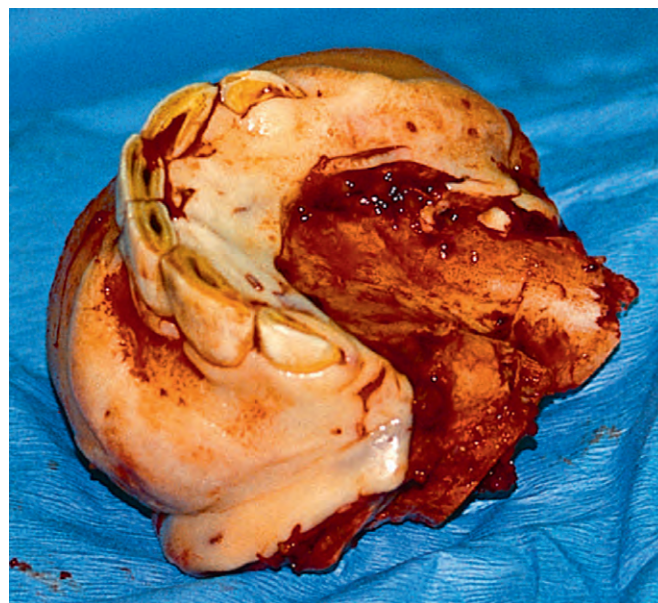


Fig. 19.27 Transected portion of the jaw containing a juvenile, ossifying fibroma.



Fig. 19.26 The mandible is transected caudal to the lesion but rostral to the caudal margin of the symphysis using an oscillating saw or obstetrical wire.



Fig. 19.28 The lingual flap and labial mucoperiosteal flaps are apposed in two layers using absorbable sutures.



Fig. 19.29 The facial appearance of a horse that has had the rostral aspect of its mandible amputated is nearly normal, except for slight flaccidity of the lower lip.

Premaxillectomy

Indications for premaxillectomy are the same as those for partial mandibulectomy, but the procedure is not performed as frequently as is partial mandibulectomy because ossifying fibroma is not as commonly encountered on the premaxillae as it is on the mandible.

Premaxillectomy is performed in a manner similar to that described for partial mandibulectomy, but the procedure is best performed with the horse anesthetized because, with this procedure, the large palatine arteries are transected. Administering a bilateral infraorbital nerve block after the horse is anesthetized allows the horse to be maintained at a lighter depth of anesthesia. The horse should receive antimicrobial and anti-inflammatory drugs prior to surgery. To perform premaxillectomy, the horse is anesthetized, and an endotracheal tube is inserted nasally, rather than orally, so that the oral cavity is maximally exposed. Anesthesia is best maintained using gas anesthesia. The horse is positioned in dorsal recumbency, and the oral cavity and surrounding skin are prepared for surgery. The upper lip is retracted and attached to the skin over the nasal bones with a towel clamp to expose the vestibule. The horse's mouth is maintained in an opened position with a wedge speculum inserted between the maxillary and mandibular cheek teeth (Fig. 19.30).

A horizontal incision through the gingiva and periosteum is made on the labial surface of the premaxillae at the dorsal border of the mass, and each end of the incision angled caudoventrally to the right and left interalveolar spaces aiming toward the caudal border of the canine teeth. Both ends of the incision are redirected rostrally from the alveolar border of the hard palate to the corner incisors and then medially until the ends of the incision meet on the midline caudal to the central incisors. Hemorrhage is controlled by ligating or cauterizing blood vessels. Using a periosteal elevator, the upper lip and nostrils are elevated from the labial

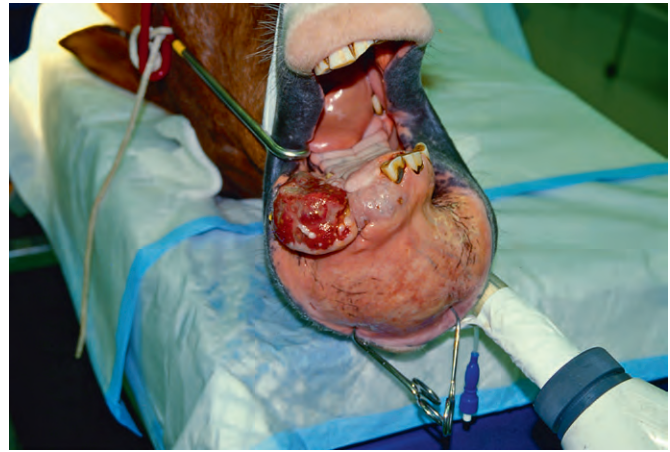


Fig. 19.30 In preparation for premaxillectomy, the upper lip is retracted with a towel clamp to expose the vestibule. The horse's mouth is maintained in an opened position with a wedge speculum inserted between the maxillary and mandibular cheek teeth.

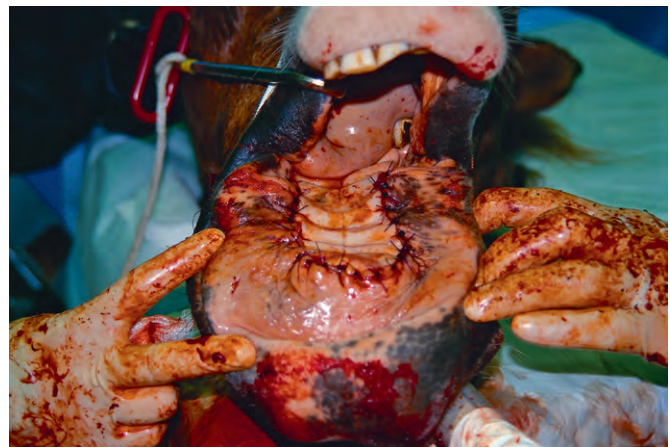


Fig. 19.31 The palatal and labial, mucoperiosteal flaps are apposed in two layers with absorbable sutures.

surface of the premaxillae and maxillae to at least 1 cm beyond the intended site of transection. The palatine, mucoperiosteal flap is also elevated to its base at the interalveolar space to expose the palatine surface of the premaxillary and maxillary bones and the palatine processes of the premaxillae.

The exposed bone of the upper jaw is then excised, caudal to the lesion, using obstetrical wire or an oscillating saw. The palatine arteries are ligated, and hemorrhage from the maxillae is ameliorated, if necessary, by applying bone wax to the cut edge of bone. If the canine teeth were transected, the portion of each tooth that remains embedded within the maxillae is removed by using a bone gouge. Sharp edges of bone are smoothed with a rongeur, and the submucosa and periosteum of the labial, mucoperiosteal flap are apposed to the submucosa and periosteum of the palatine, mucoperiosteal flap with 2-0 or 0-absorbable suture in a simple-continuous or cruciate suture pattern, and the mucosal margins of the flaps are apposed with simple-interrupted, cruciate, or vertical mattress sutures using the same suture material (Fig. 19.31). Phenylbutazone should



Fig. 19.32 The facial appearance of a horse that has had a premaxillectomy is nearly normal, but the horse's tongue may protrude intermittently between its lips.

be administered twice daily for at least several days after surgery to provide analgesia. Removing a lesion that extends beyond the canine teeth using this technique is difficult without entering the nasal cavities or removing a portion of the nasal septum.

The facial appearance of a horse that has had a premaxillectomy performed in the manner described is nearly normal (Fig. 19.32). Horses can prehend hay and grain, and can graze tall grass without difficulty but may have difficulty grasping short grass.⁶³ Initially, the horse's tongue may protrude intermittently between its lips.

Wry nose

Wry nose, or *campylorrhinus lateralis*, is a congenital deviation and shortening of the rostral aspect of the bones of the nose (i.e., maxillae, premaxillae, nasal bones, vomer bone, and nasal septum; Fig. 19.33). Wry nose has been reported to occur in a wide variety of horse breeds, but the malformation may be most prevalent in the Arabian breed, causing speculation that the condition may be genetic.⁶⁴ Inheritance of wry nose, however, has not been reported. Failure of the uterus, particularly that of primiparous mares, to expand to accommodate the fetus as it grows has also been hypothesized to be responsible for the anomaly.³¹

The nose of the affected horse may be deviated mildly or severely (e.g., up to 90°) causing all or some of the premaxillary incisors to fail to contact the mandibular incisors, but the deviation typically does not involve the maxillary cheek teeth. An affected foal may have trouble nursing,⁶⁵ and its nasal septum may be so severely deviated that it has stertorous respiration, even when resting. The nasal cavity on the convex side of the deviation is the most severely obstructed.



Fig. 19.33 Wry nose is a congenital deviation and shortening of the rostral aspect of the nose.

Wry nose may be accompanied by other abnormalities, such as cleft palate (i.e., palatoschisis) and abnormal arching of the nasal bones and hard palate.

Most affected foals are capable of nursing and can survive without treatment, but severely affected foals may be unable to nurse and may require immediate, intensive management. A slightly deviated nose may straighten as the horse matures,³¹ but for horses with moderate or severe deviation, surgical treatment is required to improve respiratory capacity, occlusion of the incisors, and cosmetic appearance. To surgically correct the deviated nose, the maxillae/premaxillae and nasal bones are transected at their point of maximum curvature and stabilized in proper alignment, and a portion of the nasal septum is excised. The nasal bones can be straightened and a portion of the septum removed 2 or 3 months after the premaxillae/maxillae are straightened,¹³ but to decrease time of convalescence and expense associated with the procedure, the entire deviation can be corrected during one anesthetic period.¹¹

The deviation is corrected with the horse anesthetized, preferably using gas anesthesia, and positioned in dorsal recumbency. The gas anesthetic agent should be delivered through an endotracheal tube inserted through a temporary tracheostomy, rather than orally, to provide maximal exposure of the oral cavity. The horse should receive an antimicrobial and an anti-inflammatory drug prior to surgery. The horse can be administered a bilateral infraorbital nerve block after anesthetic induction, so that it can be maintained at a lighter depth of anesthesia.

Before straightening the maxillae/premaxillae, a section of rib to be grafted at the site of maxillary/premaxillary osteotomy is harvested. After preparing the right or left aspect of the thorax for aseptic surgery, a 10 cm long, cutaneous incision is created over one of the most caudal ribs. The incision

begins at the costochondral junction and extends dorsally, through the skin, subcutaneous tissues, and periosteum, along the longitudinal axis of the rib. Periosteum is reflected from the exposed rib, and a 2- to 4 cm long section of rib is transected using obstetrical wire or an oscillating saw. The section of rib is stored in gauze sponges soaked in normal saline solution (0.9% NaCl) until it is inserted later, at the site of premaxillary/maxillary osteotomy, as a graft. Instillation of bupivacaine around the surgical site to desensitize the intercostal nerve of the rib may diminish pain associated with the rib resection after the horse recovers from anesthesia. The periosteum, musculature, and subcutaneous tissue are sutured separately with 2-0 absorbable suture placed in a simple-continuous pattern, and the skin is stapled. A Stent bandage sutured over the site of surgery may decrease swelling associated with the resection of the rib.

To straighten the premaxillae/maxillae, the horse's mouth is maintained in an opened position with a wedge speculum inserted between the cheek teeth or with a Guenther oral speculum inserted between the incisors. The upper lip is

retracted and attached to the skin over the bridge of the nose with a towel clamp to expose the vestibule, which is cleansed with an antimicrobial soap and rinsed with water. A 3-cm, longitudinal, mucosal incision centered at the point of greatest curvature is created in each interalveolar space over the ventral aspect of each premaxilla/maxilla (Fig. 19.34). The incision extends through the periosteum, which is elevated from the medial and lateral surfaces of the premaxilla/maxilla using a periosteal elevator.

The premaxillae/maxillae and palatine processes of the premaxillae are transected through the mucoperiosteal incisions using an oscillating saw (Fig. 19.35). The oral speculum is removed, and the transected, rostral portion of the upper jaw is rotated toward the sagittal plane of the head until the premaxillary and mandibular incisors are properly aligned. A piece of bone, 1–3 cm long, that corresponds in length to the length of the gap created on the concave side of the jaw when the maxillae/premaxillae are straightened is cut from the harvested section of rib using an oscillating saw, and this piece of bone is inserted tightly into the gap.

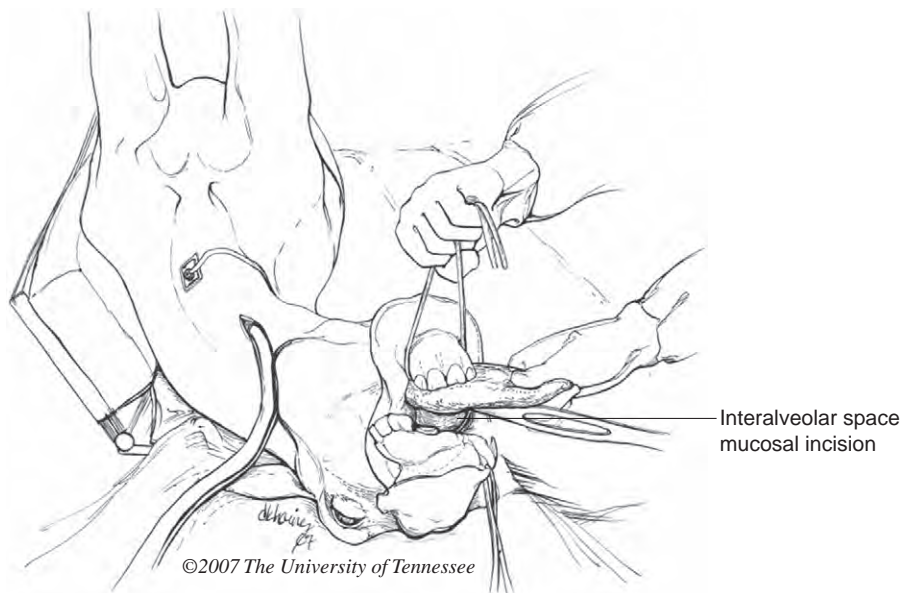


Fig. 19.34 The ventral border of each premaxilla/maxilla is exposed through a longitudinal mucosal incision at the interalveolar space centered at the site of greatest curvature. (From Schumacher J, Brink P, Easley, J, et al. Surgical correction of wry nose in four horses. *Vet Surg* 37:142–148, 2008. Illustrations by D.K. Haines © 2007 the University of Tennessee.)

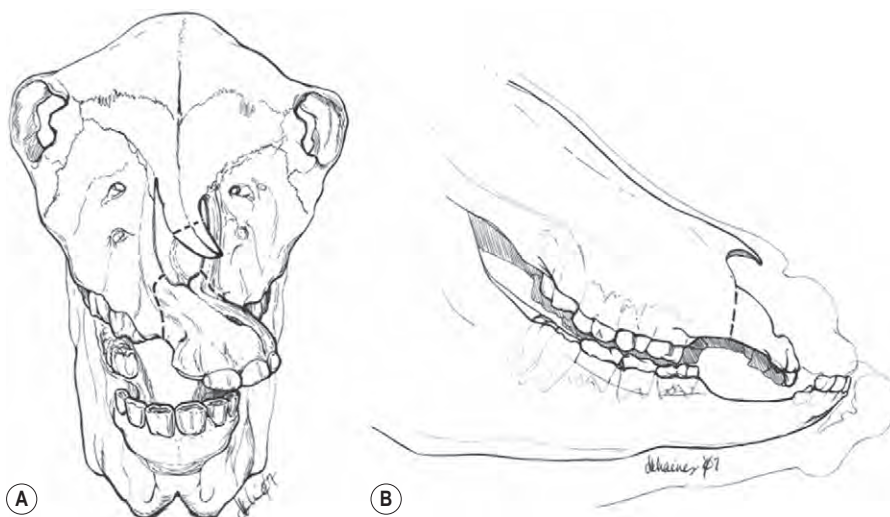


Fig. 19.35 Dashed lines indicate sites of transection of the premaxillae/maxillae and nasal bones. (From Schumacher J, Brink P, Easley, J, et al. Surgical correction of wry nose in four horses. *Vet Surg* 37:142–148, 2008. Illustrations by D.K. Haines © 2007 the University of Tennessee.)

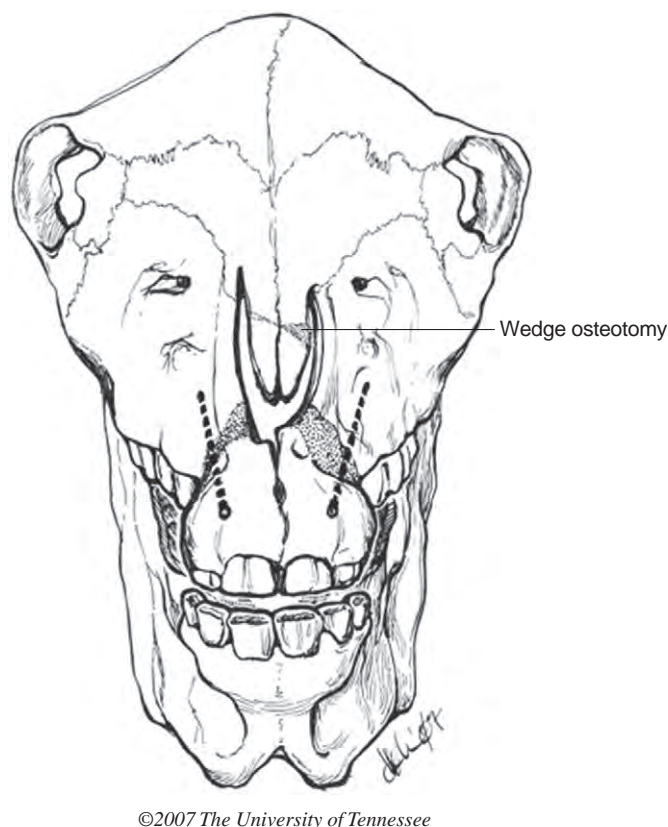


Fig. 19.36 Rostral view. Dashed lines show path of Steinmann pins for fixation of the transected premaxillae/maxillae. Stippled pattern shows gap in premaxillae/maxillae and nasal bones created by transection and realignment of the bones. The gap created when the transected nasal bones are realigned along the longitudinal axis of the skull is eliminated by performing a wedge osteotomy at the convex side of the nasal bones at the site of transection. (From Schumacher J, Brink P, Easley J, et al. Surgical correction of wry nose in four horses. *Vet Surg* 37:142–148, 2008. Illustrations by D.K. Haines © 2007 the University of Tennessee.)

The transected segment of the upper jaw is stabilized with 2, trocar-point Steinmann pins (6-mm diameter), using a high-speed, pneumatic drill (Figs 19.36 & 19.37). Each pin is inserted between the reserve crowns of the deciduous central and intermediate incisors, dorsal to the gingival margin, and driven through the medullary cavity of the transected segment of the ipsilateral premaxilla into the medullary cavity of the ipsilateral maxilla. The pin inserted on the concave side of the jaw also penetrates the medullary cavity of the rib graft. Pins are cut flush with the gingiva using a hacksaw or a bolt cutter, and the pins are driven beneath the gingiva using a mallet and a punch. The sites of gingival penetration of the pins are left unsutured to heal by second intention. The gingival incisions at the interalveolar space are closed with 2-0 absorbable suture placed in a simple-interrupted or simple-continuous pattern.

To straighten the nasal bones and remove the nasal septum, either during the same anesthetic period or 6–8 weeks later, the horse is positioned in lateral recumbency, with the concave side of the deviation uppermost. The dorsal aspect of its head is tilted 45° using a sand bag. After preparing the bridge of the nose for surgery, a 6- to 10 cm, longitudinal, curved, cutaneous incision, centered over the site of maximum deviation of the nasal bones, is made between the

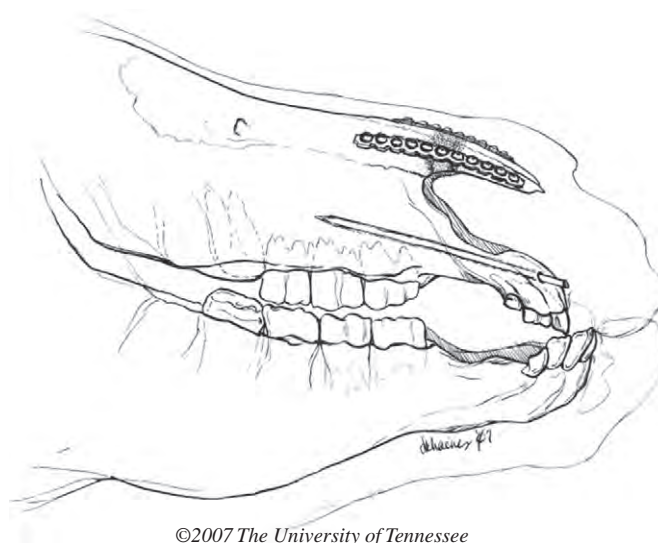
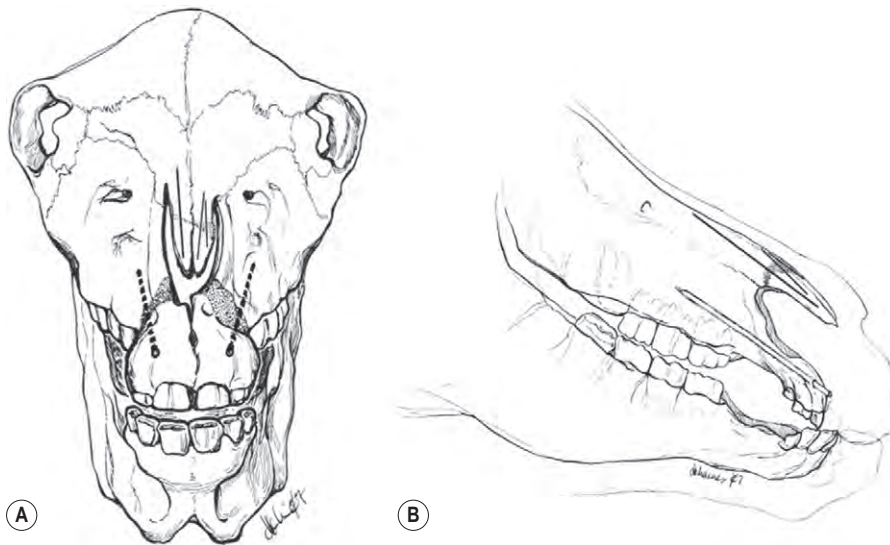


Fig. 19.37 The transected end of each nasal bone can be fixed to its parent nasal bone using a dynamic compression plate or a reconstruction plate. (From Schumacher J, Brink P, Easley J, et al. Surgical correction of wry nose in four horses. *Vet Surg* 37:142–148, 2008. Illustrations by D.K. Haines © 2007 the University of Tennessee.)

two deviated nasal bones. The nasal bones are exposed using a self-retaining retractor, and the periosteum is incised longitudinally, along the midline of each nasal bone, and the margins of the periosteal incisions are reflected.

The nasal bones are transected perpendicular to their long axis at their point of maximum curvature by using an oscillating saw, being careful not to penetrate the underlying parietal cartilage. The gap created on the concave side of the deviation when the bones are rotated into proper alignment can be eliminated by inserting a wedge-shaped segment of one of the cortices of the harvested section of rib into the gap, or the gap in the nasal bones can be eliminated by performing a wedge osteotomy at the convex side of the nasal bones at the site of transection by using an oscillating saw (Fig. 19.36).

The transected end of each nasal bone is fixed to its parent bone using a 2.7 mm reconstruction plate (Fig. 19.38). The plates are fixed with 8-mm long, 2.7-mm cortical screws. The transected segments of the nasal bones can also be fixed to the parent nasal bones with 1-mm diameter Kirschner wires by using a high-speed drill. These Kirschner wires are inserted, caudal to rostral, between the internal and external laminae of the thin, transected end of each nasal bone so that each emerges through the dorsal surface of the nasal bone and skin at the level of the external nares. The wires are then inserted retrograde, between the internal and external laminae of the parent nasal bones. The exposed ends of the wires are cut flush with skin. The Kirschner wires are more difficult to implant because the thickness of the nasal bones is not much more than the diameter of the pins, making insertion of the pins between the internal and external laminae of the bones, without penetrating the nasal or facial surface of the bone, difficult. The subcutaneous tissue is sutured with 2-0 absorbable suture in a simple continuous pattern, and the skin is stapled. A Stent bandage, composed of gauze swabs, is sutured over the surgical site.



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Fig. 19.38 (A) Rostral view. Dashed lines denote position of Steinmann pins. Thin lines in the nasal bones denote Kirschner wires. (B) Lateral view. Kirschner wires in nasal bones (denoted by thin lines) and Steinmann pins in the premaxillae and maxillae. Kirschner wires are inserted, caudal to cranial, through the transected end of each nasal bone, so that each pin emerges through the dorsal surface of the bone and skin at the level of the external nares. The wires are then inserted retrograde into the parent nasal bones. (From Schumacher J, Brink P, Easley J, et al. Surgical correction of wry nose in four horses. *Vet Surg* 37:142–148, 2008. Illustrations by D.K. Haines © 2007 the University of Tennessee.)

The nasal septum is removed with the horse in lateral recumbency with the dorsal aspect of its head elevated 45° with a sand bag, using a guarded chisel, a cartilage scissor, or obstetrical wire, using any one of various published techniques.^{66,67} Two–three centimeters of the rostral aspect of the septum are retained by the horse to provide support for the soft tissues at the rostral aspect of the nose. The caudal cut edge of the septum should lie within the nasopharynx. When only the rostral, deformed portion of the nasal septum is removed, the airways become obstructed if the caudal, cut edge of the septum thickens, because this edge lies between the conchae. The nasal chamber is packed tightly with rolled gauze, and the nostrils are sutured closed to retain the packing. The endotracheal tube is removed, either before or after the horse recovers from anesthesia, and replaced with a tracheostomy tube.

Gauze packing can usually be removed safely after 24 hours, after which the tracheostomy tube is no longer required. Phenylbutazone should be administered twice daily for at least 5 days after surgery to provide analgesia. Steinmann pins can be removed after 6 weeks, and plates or Kirschner wires can be left *in situ*. Because the upper jaw of most horses affected with wry nose is foreshortened, the horse is likely to require periodic dental care tailored to horses affected with prognathism.

Excising the nasal septum has been reported to result in collapse of the nasal bones into the nasal chamber, and collapse seems most likely to occur if the horse is <1 year old.⁶⁷ Support of the nasal bones by anchoring each transected segment of nasal bone to its parent bone with either Kirschner wires or plates and screws prevents collapse of the nasal bones. Collapse of the alar folds and ventral aspect of the nasal diverticula resulting in abnormal respiratory noise or partial obstruction of the nasal passage may be evident after surgery.¹¹ Resecting the alar folds may be necessary to resolve the abnormal respiratory noise and partial obstruction of the nasal passage.

Fixing the premaxillary incisors to the mandibular incisors with wire to increase stability at the sites of premaxillary/maxillary osteotomy has been recommended,⁶⁸ but the

additional stability provided by wiring incisors together is not necessary for healing, and horses can be returned to their normal diet as soon as they recover from anesthesia.

Distraction osteogenesis may be another effective method of correcting wry nose.⁶⁹ Using this technique, the premaxillae/maxillae are partially transected at their point of maximum curvature, and a monolateral distraction external skeletal fixator applied to the concave side of the deformity is used to periodically distract pins inserted rostral and caudal to the osteotomy.⁶⁹ Using this technique, the nasal bones and nasal septum, in addition to the premaxillae/maxillae, apparently also straighten. A disadvantage of using distraction osteogenesis to correct wry nose is that the horse must be hospitalized for a prolonged time so that the external fixator can be frequently adjusted to maintain a distractive force. Danger of injury to the dam from the protruding pins may prohibit use of the device to correct wry nose of a nursing foal.

Oromaxillary sinus fistula

A relatively common complication of repulsion of one or more of the caudal four maxillary cheek teeth is formation of an oromaxillary sinus fistula (orosinus or oro-antral fistula) resulting in contamination of the paranasal sinuses with feed.^{70,71} This complication occurs in up to 33% of horses suffering apical dental infection of one or more of the caudal maxillary cheek teeth (Triadan 09–011) treated by repulsion of the infected tooth into the oral cavity.⁷¹ An oromaxillary sinus fistula can also develop secondary to an acquired or developmental diastema between two of the caudal maxillary cheek teeth.⁷² During mastication, food is compressed into the diastema, causing destruction of the periodontium that may eventually result in formation of an oromaxillary sinus fistula, especially if the horse is old, because old horses have short cheek teeth.

Repulsing a maxillary molar or the fourth maxillary premolar creates a large communication between the oral cavity and the paranasal sinuses, and the coronal aspect of

this communication is usually plugged with gauze or acrylic until its apical aspect fills with tissue. An oromaxillary sinus fistula results if this communication fails to fill with tissue. The communication may fail to heal if the alveolus becomes chronically infected, usually from sequestration of dental or osseous fragments that were either left in the alveolus at the time of surgery or from osseous sequestra that formed later due to damage to the blood supply of the alveolus caused by surgical trauma.

Premature loss of the alveolar plug or overfilling the alveolus so that the plug extends into the sinuses can also result in formation of an oromaxillary sinus fistula.^{70,71,73} When the alveolus is overfilled with the plug, the entire alveolus epithelializes around the plug, so that when the plug is removed or lost, the sinuses communicate with the oral cavity through an epithelialized alveolus. The alveolus of old horses is more likely to be overfilled than that of young horses because the alveoli of old horses are short.

Most horses with oromaxillary sinus fistula can be treated while sedated by lavaging feed and exudate from the sinuses through a trephine portal and temporarily plugging the coronal aspect of the vacant alveolus with gauze or acrylic until the apical aspect of the alveolus fills with tissue.⁷² Before sealing the oral aspect of the alveolus, epithelium that lines the alveolus and infected granulation tissue that fills it are removed by curettage. Horses with an oromaxillary sinus fistula that has occurred secondary to a diastema may also respond to plugging the oral aspect of the diastema with an acrylic, without removal of an adjacent tooth.⁷² The primary complication associated with this form of treatment is loosening or loss of the plug during the 2 to 3 weeks that it takes for granulation tissue to fill the fistula. The most effective plug is one composed of polymethylmethacrylate.⁷² To prevent the acrylic plug from loosening, the plug should not be in contact with the cheek teeth in the opposing arcade, and when the acrylic is applied, the surrounding dental

structures should be clean and dry. The fistula should be surrounded by a tooth both rostrally and caudally because the acrylic requires a hard surface to attach to. The plug can be applied *per os* or through a sinusotomy. The plug should not extend into the apical aspect of the fistula. If an overgrowth or exaggerated transverse ridge is present on opposing cheek teeth, it should be reduced.

Horses with an oromaxillary sinus fistula that is refractory to treatment by plugging the coronal aspect of the fistula with acrylic can be treated by occluding the lumen of the alveolus with the end of a transposed muscle, such as the levator nasolabialis muscle⁷⁴ or levator labii superioris muscle.⁷⁵ The levator nasolabialis muscle is difficult to mobilize, and because it is flat, it fits poorly into the oromaxillary sinus fistula.⁷⁵ The levator labii superioris muscle is ellipsoid in its transverse plane, making it ideal for filling an alveolus.

To transpose the levator labii superioris muscle to the oromaxillary sinus fistula, as described by Brink (2006),⁷⁵ the horse is anesthetized, positioned in lateral recumbency with the affected side of the head uppermost, and prepared for surgery of the oral cavity and face.

The skin over the maxilla is incised longitudinally, with the incision centered over the apex of the oromaxillary sinus fistula, and the paranasal sinuses and the opening of the fistula into the sinuses are exposed through a trephine hole. The epithelial lining of the alveolus is removed by curettage, and the sinuses and fistula are lavaged with isotonic saline solution.

The palpable tendon of the levator labii superioris muscle is exposed through a 2-cm longitudinal skin incision created directly over the tendon and transected 2 cm rostral to its musculotendinous junction (Fig. 19.39). A locking-loop suture with long tails is placed in the tendon. The muscle and tendon are bluntly separated from the underlying maxillary and nasal bones and overlying subcutaneous tissue,

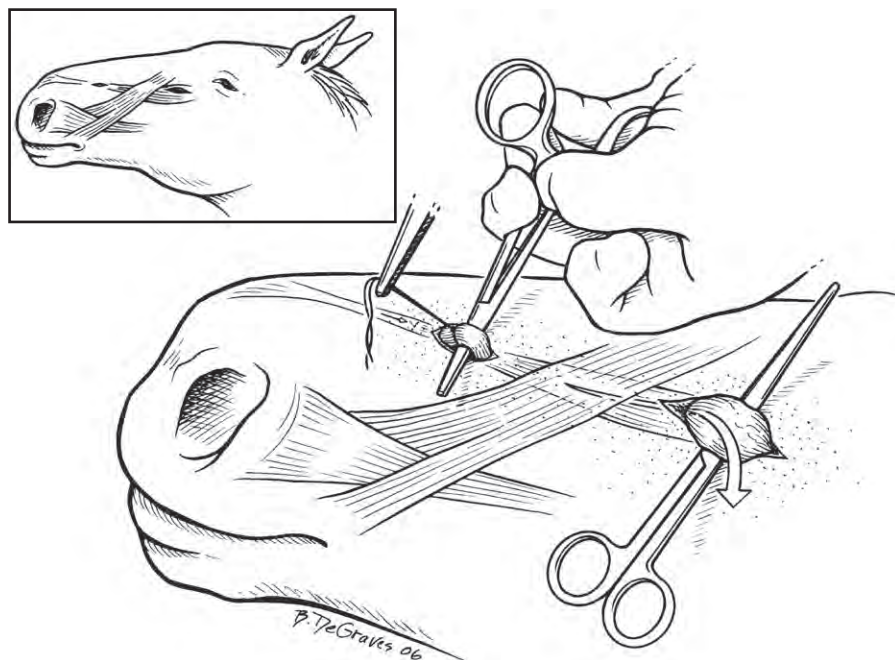


Fig. 19.39 This figure shows the site incisions created to expose the levator labii superioris muscle. (From Brink P. Levator labii superioris muscle transposition to treat oromaxillary sinus fistula in three horses. *Vet Surg* 35:596–600, 2006.)

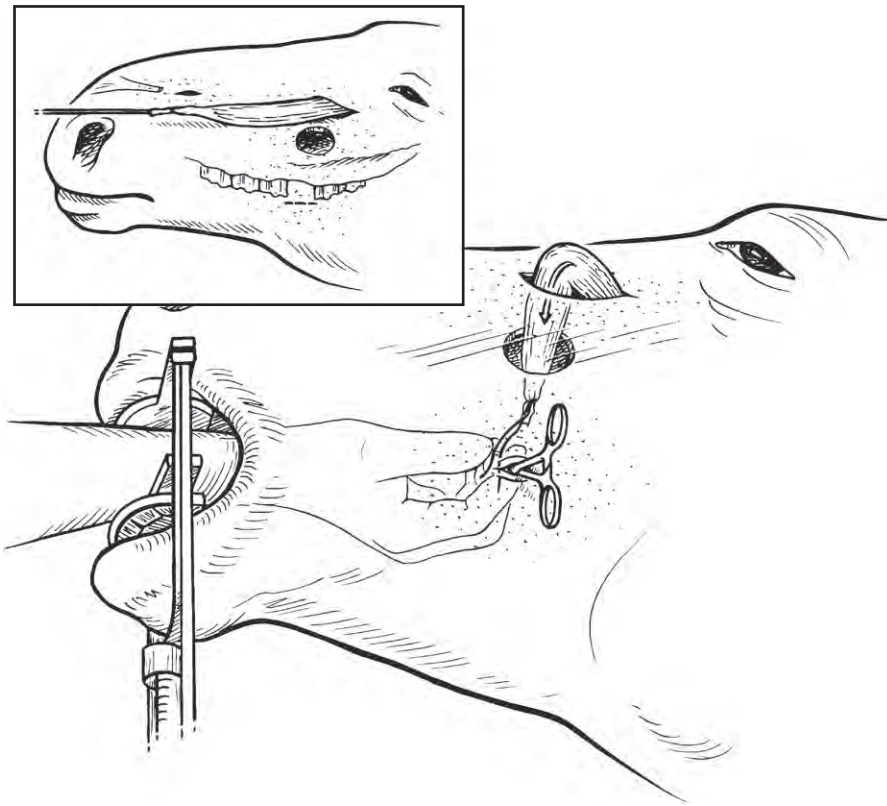


Fig. 19.40 Using a hand placed in the oral cavity, the levator labii superioris muscle is transposed through the maxillary sinus and orosinus fistula. (From Brink P. Levator labii superioris muscle transposition to treat oromaxillary sinus fistula in three horses. *Vet Surg* 35:596–600, 2006.)

using scissor dissection through the small incision created to expose the tendon and through the dorsal margin of the cutaneous incision over the maxilla, to the muscle's origin rostral to the eye.

A grasping forceps is inserted subcutaneously at the dorso-rostral margin of the incision over the maxilla and advanced rostrally beneath the levator nasolabialis muscle until it emerges at the incision created to expose the tendon of the levator labii superioris muscle. The ends of the suture in the tendon are grasped with the forceps, and by pulling them caudoventrally, the muscle and its tendon are retroverted into the incision over the maxilla (Fig. 19.40). A 2-cm, longitudinal, buccal skin incision is created adjacent to the oral aspect of the oromaxillary sinus fistula, and the jaws of a mosquito forceps are forced into the oral cavity through this incision. The suture ends are inserted through the oromaxillary sinus fistula into the oral cavity, and using hand assistance through the mouth, the suture ends are grasped with the forceps. By placing traction on the suture with the forceps, the tendon and muscle of the levator labii superioris are pulled into the oromaxillary sinus fistula and through the buccal incision so that the muscle completely occupies the oromaxillary sinus fistula (Fig. 19.41).

A 5-mm, longitudinal skin incision is made about 2–4 cm ventral to the buccotomy, and using a curved mosquito hemostat inserted through the incision, the skin between this incision and the buccotomy is undermined. The ends of the suture in the tendon are grasped with the forceps and pulled subcutaneously, causing the tendon to emerge at the ventral incision (Fig. 19.42). The tendon is secured under

slight tension to the skin and musculature at the ventral buccal incision with several, simple interrupted sutures.

A drain tube is placed in the space formerly occupied by the levator labii superioris muscle (Fig. 19.43). One end of the drain exits a stab incision created about 1 cm rostral to the end of the incision created over the tendon of the levator labii superioris. Another drain is placed subcutaneously at the maxillary incision. One end of this drain exits a stab incision created 1–2 cm ventral to the rostral end of the maxillary incision, and the other end exits a stab incision created 1–2 cm ventral to the caudal end of the maxillary incision (Fig. 19.43). Each end of each drain is secured with a simple-interrupted skin suture. If the sinuses must be lavaged, a Foley catheter is placed into the ipsilateral caudal maxillary sinus or conchofrontal sinus through a small trephine portal.

The ventral buccal incision, through which the tendon of the levator labii superioris muscle protrudes, is left unsutured to heal by second intention. The other incisions are closed in two layers. A Stent bandage, composed of sterile gauze sponges, is sutured over the maxillary incision with heavy, non-absorbable suture. Any space at the oral aspect of the alveolus unoccupied by muscle is filled with a dental acrylic.

The drains in the rostral wound and the maxillary wound are removed when drainage ceases. The Stent bandage is removed after 3 or 4 days, and skin sutures are removed at 2 weeks. The paranasal sinuses are lavaged once or twice daily until lavage is no longer required. The portion of muscle located within the oral cavity sloughs at about a

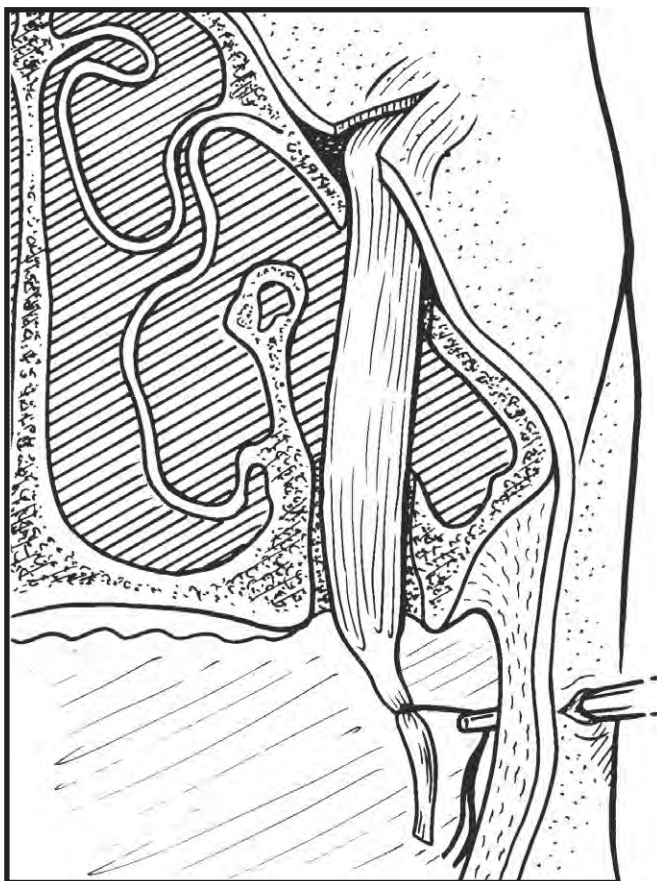


Fig. 19.41 Cross-section of head showing the position of the transposed levator labii superioris muscle and tendon through the maxillary sinus, orosinus fistula, and cheek. (From Brink P. Levator labii superioris muscle transposition to treat oromaxillary sinus fistula in three horses. *Vet Surg* 35:596–600, 2006.)

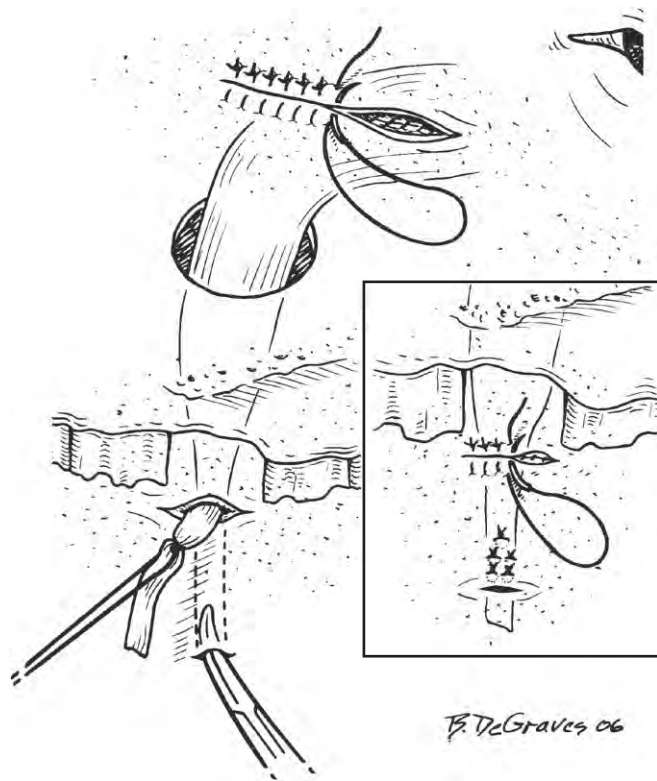


Fig. 19.42 The tendon of the levator labii superioris is tunneled subcutaneously beneath the buccotomy, exited through the buccal skin, and secured with sutures. (From Brink P. Levator labii superioris muscle transposition to treat oromaxillary sinus fistula in three horses. *Vet Surg* 35:596–600, 2006.)

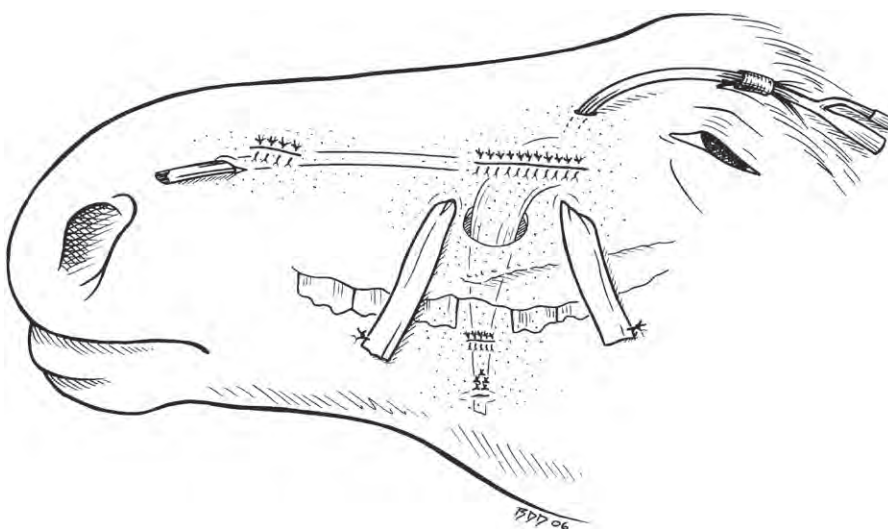


Fig. 19.43 This figure shows surgical drains placed subcutaneously and a Foley catheter placed into the paranasal sinuses for lavage of the sinuses. (From Brink P. Levator labii superioris muscle transposition to treat oromaxillary sinus fistula in three horses. *Vet Surg* 35:596–600, 2006.)

week, and is removed through the oral cavity, after cutting the sutures anchoring the tendon to the ventral buccal incision. The portion of muscle within the alveolus remains vital.

Transposing the levator labii superioris muscle and its tendon does not appear to have deleterious effects on labial

and nasal function, but care should be taken when performing a lateral buccotomy to avoid damaging the dorsal buccal branch of the facial nerve because permanent damage to this branch of the facial nerve results in permanent flaccidity of the lip. Care should also be taken to avoid damage to the duct of the parotid salivary gland.

Sinocutaneous fistula

A sinocutaneous fistula is a permanent defect that extends from the skin into the paranasal sinuses (Fig. 19.44). Those that occur in horses are most commonly the result of an open, comminuted fracture involving facial bones, but they can also result when a sinus flap or trephine portal fails to heal.

Full-thickness defects over the sinuses decrease in size after injury by centripetal movement of the tissue surrounding the defect. When the defect is large, the skin heals to the mucosa of the sinus, forming a completely epithelialized surface that prevents the defect from closing completely. The size of the defect can sometimes be decreased by incising the mucocutaneous margin of the fistula and elevating the surrounding skin to initiate contraction of the wound. A sinocutaneous fistula that cannot be healed in this manner can be healed using transposed muscle, such as the temporalis muscle,⁷⁶ the levator nasolabialis muscle,⁷⁷ or the levator labii superioris muscle,⁷⁵ or by covering the fistula with periosteum reflected from the margin of the fistula.⁷⁸

Muscle transposed to cover a sinocutaneous fistula provides vascularized tissue to the wound that is capable of accepting a rotational skin flap or a free skin graft. The temporalis muscle is in close proximity to a sinocutaneous fistula involving the conchofrontal sinus, and the levator nasolabialis and levator labii superioris muscles are in close proximity to a sinocutaneous fistula involving the rostral or caudal maxillary sinuses. To heal a sinocutaneous fistula by transposing a muscle, the horse is anesthetized and positioned in lateral recumbency with the side of the head containing the sinocutaneous fistula uppermost. The dorsal aspect of its head is tilted 45° using a sand bag. The mucocutaneous margin of the fistula is incised, and the margin of the skin surrounding the fistula is elevated. A skin incision is made over or close to the insertion of the muscle to be transposed, and through this incision the muscle or its tendon is transected. A locking-loop suture with long tails is placed in the severed end of the muscle or tendon, and the muscle is bluntly freed from its fascial attachments, using scissor dissection through the small incision created to

expose the muscle or tendon, and through the margin of the sinocutaneous fistula. A grasping forceps is inserted and advanced subcutaneously at the margin of the fistula until it emerges at the incision created to expose the muscle to be transposed. The ends of the suture in the muscle or tendon are grasped with the forceps, and by placing traction on them, the muscle is pulled beneath skin interposed between its transected end and the sinocutaneous fistula. The fistula is covered with the transposed muscle, and the muscle is sutured to fascia surrounding the fistula. The muscle is covered with a rotational skin flap or a free, full-thickness or split-thickness, meshed or non-meshed skin graft.

A sinocutaneous fistula can be healed with one large periosteal flap that covers the fistula or two, small periosteal flaps that are joined over the center of the fistula.⁷⁸ This surgery is best performed with the horse anesthetized and in lateral recumbency with the side of the head containing the fistula uppermost. The dorsal aspect of the head is tilted 45° using a sand bag, and the skin around the defect is prepared for aseptic surgery. The mucosa is separated from the skin around the mucocutaneous border of the fistula with a scalpel, and skin surrounding the fistula is freed from its underlying subcutaneous tissue. The periosteum adjacent to the fistula is exposed by creating a rotational skin flap adjacent to the fistula. A curved incision is made through the periosteum on opposite sides of the fistula, unless periosteum is available on only one side. Each incision is slightly longer than the length of the fistula and curved away from the fistula. The periosteum within the curved incision on each side is elevated toward the fistula, creating two flaps, each of which remains attached at its base, which is the border of the fistula. The periosteal flaps are sutured together with the inner, or osteogenic, layer outermost over the defect, using simple interrupted, absorbable sutures. The rotational skin flap is sutured over the periosteal flap. Subcutaneous tissue exposed by covering the defect with the rotated skin flap can be covered with a full-thickness or split-thickness, meshed or non-meshed skin graft (Fig. 19.45). The full-thickness graft is harvested from the pectoral region and the split-thickness skin graft is harvested from the ventral



Fig. 19.44 This horse has a permanent defect (i.e., sinocutaneous fistula) that extends from the skin into the paranasal sinuses.



Fig. 19.45 Same horse as in Fig. 19.44 after sinocutaneous fistula was closed using periosteal and rotational skin flaps. Subcutaneous tissue exposed by the rotational skin flap has been covered with a full-thickness, meshed skin graft procured from the pectoral region.

aspect of the abdomen. A non-adherent dressing is placed over the surgery site, and the dressing is covered with a Stent bandage or gauze pads and elastic adhesive tape. The site from which the full-thickness graft was obtained is sutured in two layers.

The osteogenic, or cambium, layer of the periosteal flaps forms new bone, and bone denuded of periosteum to create the periosteal flaps forms new periosteum.⁷⁸ Cancellous

bone, harvested from the sternum or wing of the ilium, can be used to augment periosteal bone formation, but is not necessary for the successful closure of the defect. Creating two small periosteal flaps, rather than one large flap, is more effective at preserving the blood supply to the edges of the flaps, but creating two flaps may be difficult if the fistula is in an area where periosteum is available on only one side of the lesion.

References

1. Roberts EW. Bone physiology, metabolism, and biomechanics in orthodontic practice. In: Graber TM, Vanarsdall RL, eds. *Orthodontic practice, current principles, and techniques*, 2nd edn. Mosby, St Louis, 1994, pp 193–234
2. Fletcher B. Orthodontic treatment, case report update. *Horse Dentistry and Biting Journal* 2008; 1: 18
3. Galloway SS. An expansion screw device to facilitate eruption of a mandibular premolar in a horse. In: *Proceedings of the 22nd Annual Vet Dental Forum*, Jacksonville, 2008, p. 105
4. Klugh DO. Acrylic bite plane for treatment of malocclusion in a young horse. *J Vet Dent* 2004; 21: 84–87
5. Easley J. Equine orthodontics. In: *Proceedings of the American Association of Equine Practitioners Focus on Dentistry*. Indianapolis, 2006, pp 118–126
6. Wiggs RB, Lobprise HB. *Veterinary dentistry principles and practice*. Lippincott-Raven, Philadelphia, 1997, pp 435–481
7. Nanci A. *Ten Cate's Oral histology, development, structures and function*, 6th edn. Mosby, St Louis, 2003, pp 49–51
8. Wolff J. *The law of bone remodeling*. (Translation of 1892 German edition.) Verlag Springer, New York, 1986
9. Graber TM. Functional appliances in orthodontics. In: Graber TM, Vanarsdall RL, eds. *Orthodontic practice, current principles, and techniques*, 2nd edn. Mosby, St Louis, 1994, pp 383–436
10. Musich DR. Orthodontics and orthognathic surgery. In: Graber TM, Vanarsdall RL, eds. *Orthodontic practice, current principles, and techniques*, 2nd edn. Mosby, St Louis, 1994, pp 835–907
11. Schumacher J, Brink P, Easley J, Pollock P. Surgical correction of wry nose in four horses. *Vet Surg* 2008; 37: 142–148
12. Tucker MR. Correction of dentofacial deformities. In: Peterson LJ, Hupp J, Ellis E, III, Tucker MR, eds. *Contemporary oral and maxillofacial surgery*, 2nd edn. Mosby, St Louis, 1993, pp 613–656
13. Valdez H, McMullan WC, Hobson HP, Hanselka DV. Surgical correction of deviated nasal septum and premaxilla in a colt. *J Am Vet Med Assoc* 1978; 173: 1001–1004
14. Verwilghen D, Galen G, Vanderheyden L, et al. Mandibular osteodistraction as a corrective method for deep bite II malocclusions in the horse. *Vet Surg*, 2008
15. Uhlir C. Survey of selected dental abnormalities in 233 horses. *Proceedings of the 33rd Annual Meeting of the American Association of Equine Practitioners*, 1987, pp 577–583.
16. Joest E. *Handbuch der speziellen pathologischen Anatomie der Haustiere*, Vol. V/I. Verlag Paul Parey, Berlin, 1970
17. Miles AEW, Grigson C. *Colyer's Variations and diseases of the teeth of animals*, rev edn. Cambridge University Press, Cambridge, 1990
18. Dixon PM. Removal of equine dental overgrowths. *Equine Veterinary Education*, 2000; 12(2): 68–81
19. Dixon PM. The gross, histological and ultrastructural anatomy of equine teeth and their relationship to disease. In: *Proceedings of 48th Annual Convention of the American Association of Equine Practitioners*, 2002, pp 421–437
20. Dixon PM, Tremaine WH, McGorum BC, et al. Equine dental disease – a long term study of 400 cases, part 1: Introduction and disorders of incisor, canine and first premolar teeth. *Equine Vet J* 1999; 31: 369–377
21. Dixon PM, Tremaine WH, McGorum BC, et al. Equine dental disease – a long term study of 400 cases, part 2: Disorders of development, eruption and variations in position of cheek teeth. *Equine Vet J* 1999; 31: 519–528
22. Baker GJ. Oral diseases of the horse. In: Harvey CE, ed. *Veterinary dentistry*, WB Saunders, Philadelphia, 1985, pp 220–221
23. Faragella F. Rotated maxillary fourth premolar in a horse. *J Vet Dent* 2004; 21: 226–227
24. Earley ET. How to manage maleruptions of the upper forth premolars in the miniature horse. *Proceedings of the 53rd Annual Convention of the American Association of Equine Practitioners*, 2007, pp 487–497
25. DeBowes RM. Brachygnathia. In: White, AN, Moore JN, Lippincott JB, eds. *Current practice of equine surgery*, Philadelphia, 1990, pp. 469–472
26. McIlwraith CW. Equine digestive system. In: Jennings PB, ed. *The Practice of large animal surgery*, WB Saunders, Philadelphia, 1984, pp 558–560
27. Burdach J, Mooney MP. The relationship between lip pressure following lip repair and craniofacial growth: an experimental study in beagles. *Plastic and Reconstruction Surgery* 1984; 73(4): 544–555
28. Petrovik AG. Experimental and cybernetic approaches to the mechanism of action of functional appliances of mandibular growth. In: McNamara JA (monograph), ed. *Malocclusion and the periodontium*, Cranial Growth Series, 1984, p. 15
29. Easley J. Basic equine orthodontics. In: Baker GJ, Easley J, eds. *Equine dentistry*, 2nd edn. Elsevier, Edinburgh, 2005, pp 249–266
30. Crowe MW, Swerczek TW. Equine congenital defects. *Am J Vet Res* 1985; 46: 353–358
31. Vandeplasche M, Simoons P, Bouters R, et al. Aetiology and pathogenesis of congenital torticollis and head scoliosis in the equine foetus. *Equine Vet J* 1984; 16: 419–424
32. McNamara JA. Neuromuscular and skeletal adaptations to altered function in the orofacial region. *American Journal of Orthodontics* 1973; 64: 136, 189, 578
33. McNamara JA. Functional determinants of craniofacial and shape. *European Journal of Orthodontics* 1980; 2: 131
34. Hennek PR, Harvey CE. Craniofacial development and growth in the dog. *Journal of Veterinary Dentistry* 1992; 9(2): 11–18
35. Harvey CE, Penny RHC. Oral and dental diseases in pigs. In: Harvey CE, ed. *Veterinary Dentistry*, WB Saunders, Philadelphia, 1985, pp 481–551
36. Angle EH. *The angle system of regulation and retention of the teeth and treatment of fractures of the maxillae*, 5th edn. SS White Manufacturing, Philadelphia, 1899
37. Hennek PR, Harvey CE, Emily PP. The angle classification of malocclusion: is it appropriate for use in veterinary dentistry? *Journal of Veterinary Dentistry* 1992; 9(3): 10–12
38. Academy of Veterinary Dentistry. Dental abbreviations, Equine dental abbreviations Suppl, 2007, pp 15–17

39. Carmalt JL. Understanding the equine diastema. *Equine Veterinary Education* 2003; 5(1): 43–44
40. Greene S, Basile JP. Recognition and treatment of equine periodontal disease. In: *Proceedings of the 48th Annual Convention of the American Association of Equine Practitioners*, 2002, pp 463–466
41. Vlaminc L. Post-extraction molariform tooth drift and alveolar grafting in horses. PhD thesis. University of Ghent, Ghent, 2007, pp 209–223
42. Vlaminc L, Hays L, Maes D, et al. Use of a synthetic bone substitute to retard molariform tooth drift after maxillary tooth loss in ponies. *Vet Surg* 2006; 35 (7): 587–588
43. Carmalt JL, Townsend HGG, Allen LA. Effect of dental floating on the rostrocaudal mobility of the mandible of horses. *J Am Vet Med Assoc* 2003; 23: 666–669
44. Lear TL, Cox JH, Kennedy GA. Autosomal trisomy in a thoroughbred colt: 65, XY, +31. *Equine Vet J* 1997; 31(1): 85–88
45. McLaughlin GB, Doige LE. Congenital musculoskeletal lesions and hyperplastic goiter in foals. *Canadian Veterinary Journal* 1981; 22: 130
46. Becker E. Zähne. In: *Handbuch der speziellen pathologischen Anatomie der Haustiere*, 3rd edn. Vol 5, Digestionsapparat. Verlag Paul Parey, Berlin, 1970, pp 83–313
47. Duke A. Equine bit analysis. Annual Conference of American Veterinary Dental Society, Handout notes. New Orleans, 1989
48. Boero M. Correction of brachygnathism in foals. In: Allen T, ed. *Manual of equine dentistry*. Mosby, St Louis, 2003, p. 173
49. Pence P, Wilewski K. Newborn, weanling and adolescent horse dentistry. In: Pence P, ed. *Equine dentistry: a practical guide*. Lippincott, Williams and Wilkins, Baltimore, 2002, pp 115–139
50. Dixon PM, Hawkes C, Townsend W. Complications of equine oral surgery. *Vet Clin North Am Equine Pract* 2009; 24: 499–514
51. Jayo M, Leipold HW, Dennis SM, Eldridge FE. Brachygnathia superior and degenerative joint disease, a new lethal syndrome in Angus calves. *Veterinary Pathology* 1987; 24: 148–155
52. Mitz C, Allen T. Dentistry in miniature horses. In: Allen T, ed. *Manual of equine dentistry*. Mosby, St Louis, 2003, pp 175–192
53. Pence P, Mitz C. Miniature horse dentistry. In: Pence P, ed. *Equine dentistry: a practical guide*. Lippincott, Williams, and Wilkins, Baltimore, 2002, pp 191–199
54. Baker GJ. Problems involving the mouth. In: Reed S, Bayly W, eds. *Equine internal medicine*. WB Saunders, Philadelphia, 1998, p. 605
55. Easter JL, Watkins JP. Diseases of the head and neck. In: Colahan PT, Merritt AM, Moore JN, Mayhew JC, eds. *Equine Medicine and Surgery*. Mosby, St Louis, 1999, p. 1669
56. Stashak TS. *Equine wound management*. Lea and Febiger, Philadelphia, 1991, pp 139–144
57. American Veterinary Medical Association Membership Directory. Principles of veterinary medical ethics of the AVMA (1999 revision) IV. Therapies, Genetic Defects, 2003, 36
58. Schumacher J, Dutton DM, Murphy DJ, et al. Paranasal sinus surgery in sedated, standing horses. *Vet Surg* 2000; 29: 173–177
59. Doherty T, Valverde A. Management of sedation and anesthesia. In: Doherty T, Valverde A, eds. *Manual of equine anesthesia and analgesia*. Blackwell, Ames, Iowa, 2006, pp 206–208
60. Quinn GC, Kidd JA, Lane JG. Modified frontonasal sinus flap surgery in standing horses: surgical findings and outcomes of 60 cases. *Equine Vet J* 2005; 37: 138–142
61. Schumacher J, Honnas C, Smith B. Paranasal sinusitis complicated by inspissated exudate in the ventral conchal sinus. *Vet Surg* 1987; 16: 373–377
62. Richardson DW, Evans LH, Tulleners EP. Rostral mandibulectomy in five horses. *J Am Vet Med Assoc* 1991; 199: 1179–1182
63. Schumacher J, Kemper DL, Helman RG, Edwards JL. Removal of the premaxillae of a horse. *J Am Vet Med Assoc* 1996; 209: 118–119
64. Baker GJ. Abnormalities of development and eruption. In: Baker GJ, Easley J, eds. *Equine dentistry*. WB Saunders, Philadelphia, 1999, pp 49–59
65. McKellar GM, Collins AP. The surgical correction of a deviated anterior maxilla in a horse. *Australian Veterinary Journal* 1993; 70: 112–114
66. Doyle AJ, Freeman DE. Extensive nasal septum resection in horses using a 3-wire method. *Veterinary Surgery* 2005; 34: 167–173
67. Tulleners EP, Raker CW. Nasal septum resection in the horse. *Veterinary Surgery* 1983; 12: 41–47
68. Auer JA. Craniomaxillofacial disorders. In: Auer JA, Stick JA, eds. *Textbook of equine surgery*, 3rd edn. Elsevier, Philadelphia, 2006, pp 1341–1362
69. Puchol JL, Herrán R, Durall L, et al. Use of distraction osteogenesis for the correction of deviated nasal septum and premaxilla in a horse. *J Am Vet Med Assoc* 2004; 224: 1147–1150
70. Baker GJ. Some aspects of equine dental disease. *Equine Vet J* 1970; 2: 105–110.
71. Orsini PG, Ross MW. Retrospective study of tooth root abscesses in 110 horses. *Proceedings of the 16th Annual Veterinary Surgical Forum*, 1988
72. Dixon PM, Hawkes C, Easley J. Standing treatment of oronasal and orosinus fistulas. *Proceedings of the American College of Veterinary Surgeons ACVS Symposium Equine and Small Animal*, 2007
73. Prichard MA, Hackett RP, Erb HN. Long-term outcome of tooth repulsion in horses: a retrospective study of 61 cases. *Vet Surg* 1992; 21: 145–149
74. Orsini P, Ross M, Hamir A. Levator nasolabialis muscle transposition to prevent an orosinus fistula after tooth extraction in horses. *Vet Surg* 1992; 21: 150–156
75. Brink P. Levator labii superioris muscle transposition to treat oromaxillary sinus fistula in three horses. *Vet Surg* 2006; 35: 596–600
76. Campbell ML, Peyton LC. Muscle flap closure of a frontocutaneous fistula in a horse. *Vet Surg* 1984; 13: 185–188
77. Dart A, Best P, Peatfield J. Reconstruction of a maxillary sinus defect in a horse using a levator nasolabialis muscle flap. *Australian Veterinary Journal* 1994; 71: 379–380
78. Schumacher J, Auer J, Shamis L. The use of periosteal flaps to repair facial defects in two horses. *Vet Surg* 1985; 14: 235–239

Exodontia

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Introduction

A tooth should be removed only when it is proven to be diseased and only after other more conservative treatments to salvage the tooth have failed or are likely to fail. Because of technical limitations of preserving a hypsodont tooth by endodontic treatment, removing a severely diseased cheek tooth often remains the only effective treatment for horses with a diseased tooth. Extraction of a cheek tooth from horses was described early in the veterinary literature¹ and, after the advent of anesthesia, was one of the first surgical procedures to be performed with the horse anesthetized. It remains the most frequently performed oral surgery of the horse.

Indications for dental extraction

The most common indication for removing a tooth is apical dentoalveolar infection, which results most commonly from periodontal disease, infundibular caries of a maxillary cheek tooth, or hematogenous deposition of bacteria into the pulp (i.e., anachoretic infection). Other indications for removing a tooth include: a retained deciduous incisor or premolar; a tooth affected by severe, irreversible periodontal disease; a loose tooth; a tooth whose clinical crown has fractured; a supernumerary, displaced, or misaligned tooth causing clinical signs of disease; an impacted tooth; a tooth that has become non-vital because of fracture of the jaw; a tooth with an overgrowth so severe that it has caused severe, soft-tissue trauma; a tooth that interferes with orthodontic surgery; and a tooth that has become neoplastic.

Evidence that a tooth is diseased is usually obtained from clinical signs and oral and radiographic examination, but other imaging techniques, such as computed tomography, magnetic resonance imaging, or nuclear scintigraphy, must sometimes be used to determine if a tooth is diseased. Dental extraction to resolve signs of dental disease is contraindicated when the identity of the tooth causing these signs is not firmly established.²

The technique used to remove a tooth depends on the tooth involved, the nature of the disease affecting that tooth,

and the preference of the veterinary surgeon performing the procedure. Regardless of the technique used, the principle rule of removing a tooth, summarized by Lane,³ 'to remove the tooth, the whole tooth and nothing but the tooth,' remains valid in all situations, excluding those where extensively diseased bone surrounds the tooth. The principles of dental extraction in human beings, summarized by Shira, are valid for the horse.⁴ These principles are:

1. to obtain adequate access to the periodontium
2. to create an unimpeded pathway for removal of the tooth
3. to use controlled force to remove the tooth.

When a diseased cheek tooth can be removed by an intra-oral approach, using a dental extractor, complications are few and the horse requires little aftercare, but despite its advantages, extraction *per os* of a diseased tooth along its natural path of eruption is often not feasible, and other methods of removal must be considered. Removing a tooth using an intra-oral approach is difficult or impossible when the tooth's clinical crown cannot be grasped with a dental extractor (e.g., when a portion of the clinical crown is missing), when its reserve crown is fractured, when its clinical crown is brittle because of extensive dental caries, or when the reserve crown of the tooth is so large from hyperplasia of the cementum or a dental tumor that it cannot traverse the alveolus. When the tooth cannot be removed using an intra-oral approach, the tooth must be removed by an extra-oral approach, which entails either repulsing the tooth into the oral cavity, using a mallet and a punch, or prying the tooth from the alveolus through a buccotomy after removing the lateral plate of alveolar bone.

Removal of a tooth, regardless of the technique used, has historically been thought of as a straightforward, unsophisticated procedure, but the high incidence of complications reported, particularly that associated with repulsion, shows that removing a tooth can be a technically difficult procedure that demands careful preparation, specialized equipment, and meticulous attention to technique to avoid complications. Before embarking on this potentially complicated procedure, the veterinarian should discuss the potential costs and complications with the owner.

Removal of incisors

Deciduous incisors, especially the middle (Triadan 02) and corner (Triadan 03) incisors, are often involved in an avulsion fracture of the mandible or an incisive bone (pre-maxilla). Whenever possible, and whenever soft-tissue attachments remain, the teeth should be salvaged by incorporating them into the fracture repair. Many incisors that may initially appear to be devitalized can be salvaged, provided that they can be immobilized and that they remain at least partially attached to their alveolus. Removing a completely devitalized deciduous incisor has minimal effect on eruption of its permanent counterpart.

Failure of one or more deciduous incisors to shed when their permanent counterparts erupt can result in misalignment of the permanent teeth as they erupt (Fig. 20.1). These retained incisors, which usually reside rostral to the permanent incisors, rarely interfere with prehension of food, and usually present a problem only with cosmesis. A deciduous incisor can easily be removed with the horse sedated after infiltrating the surrounding gingiva with local anesthetic solution, such as mepivacaine or lidocaine. A deciduous incisor has a short reserve crown, and its periodontal attachments are easily loosened using a small, periodontal elevator (Fig. 20.2). Once loosened, the tooth can be extracted using a pair of small, wolf tooth extracting forceps (Fig. 20.3). The alveolus fills rapidly with a blood clot, which is soon replaced by granulation tissue, then by fibrous tissue, and finally by bone.

Removal of supernumerary, permanent incisors

Supernumerary, permanent incisors occur frequently and vary in number from one to several. The supernumerary permanent incisor usually has an occlusal surface that appears similar to that of a normal incisor and has a reserve crown that is often equal in length and shape to that of a normal incisor (Figs 20.4 & 20.5). Supernumerary teeth that



Fig. 20.1 Retained middle upper deciduous incisor. A retained incisor usually resides rostral to the permanent incisors. These shallow-rooted teeth can usually be removed without difficulty with the horse sedated, using local analgesia.



Fig. 20.2 Small periodontal elevators, such as these, are suitable for elevating incisors and 'wolf teeth.'



Fig. 20.3 Small dental extractors, such as these, are suitable for removing retained deciduous incisors.



Fig. 20.4 Supernumerary incisors are difficult to distinguish from the normal incisors by their occlusal appearance and are usually of no clinical significance.



Fig. 20.5 Temporary and permanent supernumerary incisors removed from a pony.

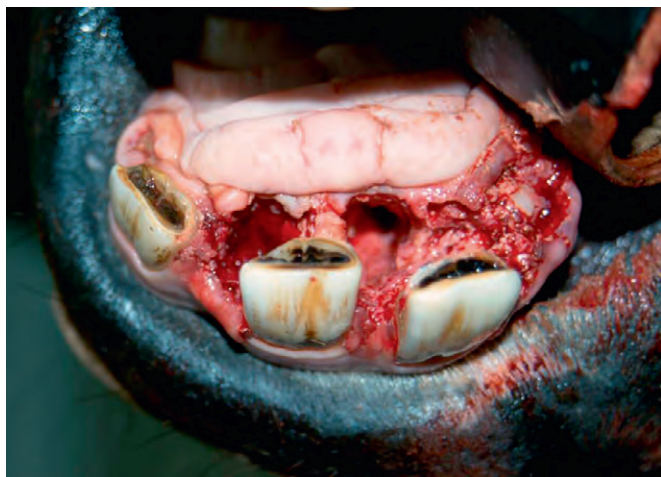


Fig. 20.6 Their deep reserve crowns and their close proximity to each other make supernumerary incisors difficult to extract. The remaining teeth align to provide a normal or near normal appearance to the incisors. The benefit of removing supernumerary incisors is usually only cosmetic. This picture shows an incisor arcade after permanent supernumerary incisors were removed.

resemble teeth of the normal series in crown and root morphology are sometimes referred to as supplemental teeth. Radiographic examination is often useful to detect unerupted permanent incisors, but despite careful physical and radiographic examination of the incisors, distinguishing a supernumerary tooth from the usually identical surrounding normal teeth can often be impossible. A supernumerary permanent incisor imparts an asymmetric appearance to the incisor arcade but usually causes minimal signs of disease, and affected horses rarely suffer any difficulty in prehending feed. Removing a supernumerary incisor is usually unnecessary and serves only to improve the cosmetic appearance of the horse. Although removing a supernumerary incisor leaves a large gap between the remaining teeth, this gap disappears as the teeth realign (**Fig. 20.6**).

Removing a supernumerary incisor can be difficult because these incisors have an extensive reserve crown and are in close proximity to other teeth. Removing a supernumerary



Fig. 20.7 These avulsed mandibular incisors have been salvaged by reducing the fracture and immobilizing it with cerclage wire.

permanent incisor may necessitate that the horse be anesthetized, especially if more than one tooth is to be removed, because most horses are more sensitive to concussion of the incisors than to concussion of the cheek teeth. If the horse is compliant, however, a single, supernumerary, permanent incisor can usually be removed with the horse sedated after providing analgesia with an alpha-2 agonist and an opiate and desensitizing the tooth and associated structures with a maxillary or mandibular nerve block. (See Ch. 15).

A supernumerary, permanent incisor can be removed by gradually elevating its periodontal attachment around the entire circumference of the tooth until the tooth is loose enough that it can be extracted with minimal force. Teeth that are difficult to loosen can be extracted after raising a gingival flap by making two parallel, gingival incisions along the peripheral margins of the reserve crown to expose the labial alveolar plate, which is removed using a narrow (e.g., 1 cm wide) osteotome. The periodontal ligament is gradually severed using a periodontal elevator until the incisor is loose enough to be extracted with a small incisor extraction forceps.

Removal of incisors after trauma

Incisors that have separated totally from their gingival attachments as a result of avulsion of a portion of the incisive bone or rostral aspect of the mandible should be removed. Avulsed incisors that retain some gingival attachments may remain vital and can often be salvaged by debriding the wound and reducing and immobilizing the fracture (**Fig. 20.7**).

Removing canine teeth

The few indications for removing canine teeth include severe periostitis, often associated with bit injuries, and pulpitis, often resulting from fracture of the tooth or its alveolus. Canine teeth severely affected by the odontoclastic resorption and hypercementosis syndrome may also require

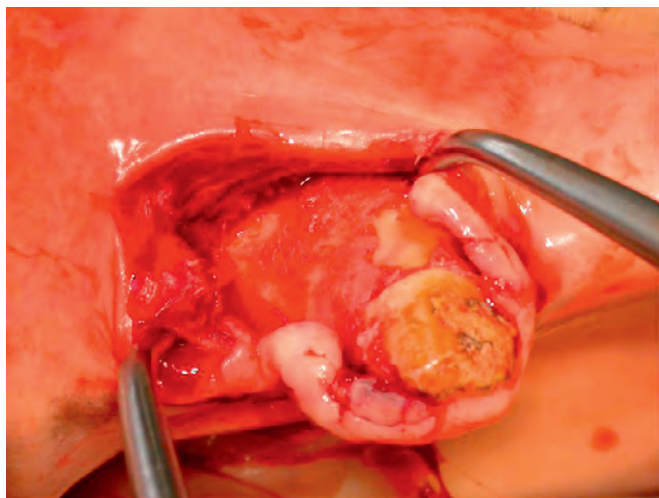


Fig. 20.8 This canine, which was sensitive to percussion, was desensitized with a mandibular alveolar nerve block before its gingival attachments were elevated. Canines have an extensive reserve crown, and so, to extract a canine, a lateral alveolar osteotomy is often required.

extraction. Pulpitis can result in a painful, focal, apical abscess, which in some cases discharges through a gingival tract. Removing the entire canine to prevent injury to other horses or to facilitate dental examination is contraindicated and may result in spillage of the tongue from the mouth, which may affect the horse's performance, if the horse is a show horse. Excessively sharp canines can be reduced slightly and profiled using a rotating diamond burr.

Loose canines can be extracted using an incisor forceps or a small animal dental forceps after elevating the periodontium. The long, curved alveolus in which the apical portion of the canine is embedded makes removing a canine with an intact periodontium difficult. Removing a canine is facilitated by desensitizing the surrounding gingiva with local anesthetic solution and raising a gingival flap to expose the labial aspect of the alveolar bone, which is removed with an osteotome (Fig. 20.8). The periodontal ligament surrounding the reserve crown can then be severed with a periodontal elevator until the tooth is loose enough to be extracted. When extracting a mandibular canine, care must be taken to avoid damaging the mandibular alveolar nerve when elevating the gingival flap. An apically infected canine can sometimes be salvaged using endodontic treatment.

Extracting wolf teeth

The first premolar (Triadan 05), commonly referred to as the 'wolf tooth', is highly variable in position, shape, and size. Wolf teeth are commonly present in the maxillae but are present far less frequently in the mandible. The size of the clinical crown of a wolf tooth is a poor indicator of the size of the embedded portion of the tooth. Maxillary wolf teeth are present in 40–80% of horses, but often only one wolf tooth is present.⁵ The time at which the wolf teeth erupt is variable, but most erupt when the horse is between 6 and 18 months old.

Most wolf teeth are located immediately rostral to the maxillary 2nd premolar (Triadan 106, 206), but they are not



Fig. 20.9 This picture shows a range of equipment used to elevate gingival and periodontal attachments to a wolf tooth before the tooth is extracted with small forceps.

infrequently displaced toward the buccal or palatal aspect of that tooth and may erupt far rostrally, close to the canine. Some remain subgingival and are often detected as a hard, subgingival nodule in the interdental space. An unerupted wolf tooth may occasionally be associated with gingival ulceration and may cause the horse to show signs of discomfort when it is contacted by the bit. Radiographic examination of the tooth is useful to demonstrate the size and direction of the embedded portion of the tooth before attempting to extract the tooth. An erupting canine in the interdental space of a young horse (i.e., 2- to 4-year-old) should not be mistaken for a displaced wolf tooth.

Extracting the wolf teeth to resolve biting problems was described in the 18th century,⁶ and wolf teeth are still removed today for this same reason, and sometimes because they are perceived to interfere with other dental procedures, even though scientific evidence of the benefit of extracting them is lacking. Pain or sensitivity associated with the wolf teeth, especially those that are extremely large, molarized or aberrantly placed, may result in a problem with biting or performance. Entrapment of the buccal, mucosal fold of the commissure of the lips between the bit and the wolf tooth or the rostral aspect of the 2nd premolar has been cited as a cause of discomfort and, consequently, a lack of responsiveness to the bit. Reducing the rostral and buccal aspect of the 2nd premolar (i.e., 1st cheek tooth, Triadan 06) with a rasp can be hindered by the presence of a large wolf tooth. Because of these problems associated with the wolf teeth, real or imagined, wolf teeth have traditionally been removed from young horses. This tradition may eventually slide into obsolescence.

Wolf teeth can usually be extracted *in toto* with the horse sedated and standing; administering local anesthetic solution subgingivally may ease extraction. A wolf tooth with a normal configuration can be extracted easily by circumferentially elevating its gingival and periodontal attachments using a traditional, circular 'Burgess-type' extractor, but a small, curved periodontal elevator can be used with much more precision and effectiveness (Fig. 20.9).

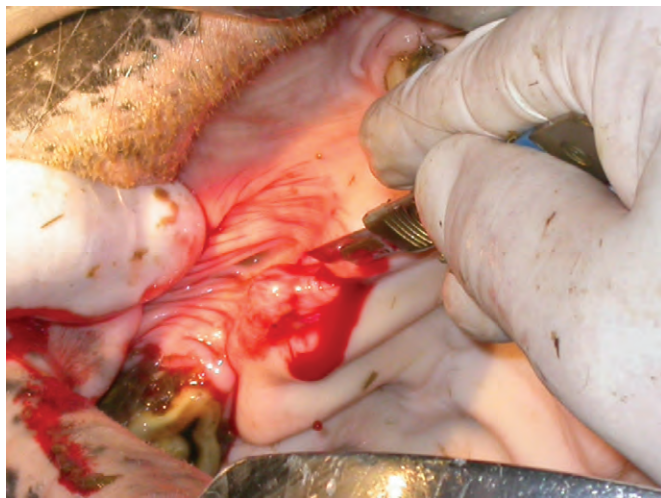


Fig. 20.10 A small, gingival incision exposes a subgingival wolf tooth for extraction.

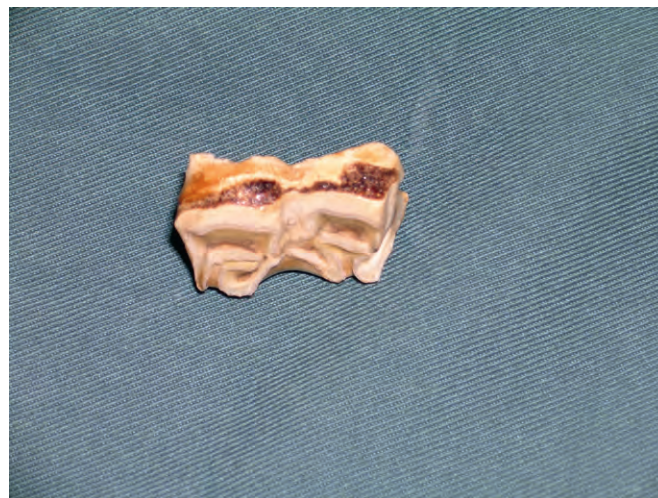


Fig. 20.12 This deciduous premolar was removed with cap extracting forceps.

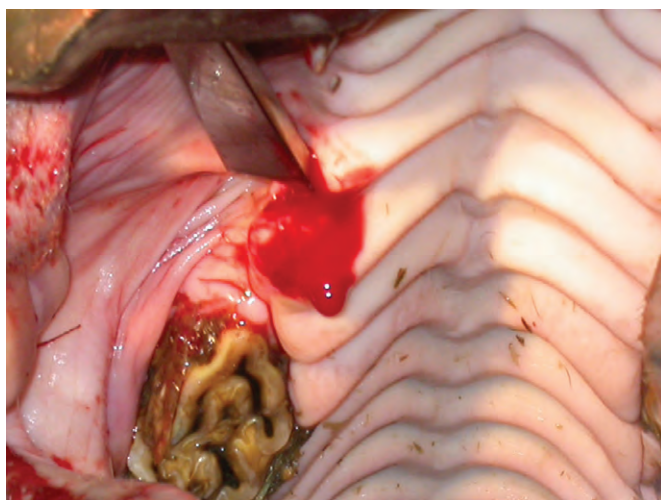


Fig. 20.11 Large, subgingival wolf tooth being extracted using a narrow osteotome placed between the tooth and the hard palate and directed caudally.

The size and position of the apical portion of an aberrant or a very large wolf tooth should be assessed radiographically before attempting to extract the tooth. After its periodontium has been elevated, the loosened tooth can be extracted using a small incisor extractor or a specialized wolf tooth extractor. A wolf tooth located subgingivally can be exposed through a small incision in the overlying gingival mucosa (Fig. 20.10). The apex of an unerupted, rostrally located, wolf tooth often extends caudally, and an osteotome or gouge placed between the tooth and palate can be used to separate the periodontium from its underlying bone (Fig. 20.11).

Failure to sufficiently loosen the periodontium surrounding a wolf tooth can result in fracture of the tooth. The retained dental fragment should be elevated and removed to assure healing of the alveolus, but an apical fragment located subgingivally rarely causes a clinical problem. After several days, a loose fragment may migrate to a more superficial

position where it can be more easily removed. Mandibular wolf teeth (Triadan 305, 405) occur rarely, but if present they can usually be palpated rostral to the first cheek tooth. They vary in size and position, but commonly they are quite small. They may be responsible for discomfort with the bit and are a noteworthy observation during a pre-purchase examination. The technique for their removal is similar to that described for removing maxillary wolf teeth.

Extracting deciduous premolars

The permanent premolars erupt, displacing the remnants of their temporary counterparts, when the horse is between approximately 2.5 and 4 years old. The age at which each permanent tooth erupts varies among breeds and among individuals within a breed. For instance, the permanent teeth of miniature horses often erupt later than those of horses of other breeds. A deciduous premolar can become retained if it becomes impacted between adjacent teeth, and if impacted, it can occasionally contribute to impaction or maleruption of the emerging permanent tooth.

Young horses sometimes develop a transient periodontitis caused by retention of feed between the exfoliating temporary tooth and the erupting permanent tooth. Periodontitis and entrapment of food around a deciduous tooth are indications that the temporary tooth should be removed. Occasionally, a remnant of a deciduous tooth becomes retained at an interproximal space, causing pain.

If the gingival attachments of a deciduous premolar are intact, the deciduous premolar should not be removed because development of the underlying permanent tooth may be incomplete. An exfoliating, deciduous premolar, or 'cap', is easily extracted using a shallow-jawed, cap extractor (Figs 20.12 & 20.13).

Extracting a permanent cheek tooth *per os*

Extraction of a tooth *per os*, performed with the horse conscious, has been practiced since the turn of the 20th century,



Fig. 20.13 The underside of this shed deciduous premolar contains some of the gingival epithelium that surrounded the emerging permanent premolar.

but the technical difficulties encountered when extracting a tooth from a poorly restrained horse and the development of improved anesthetic agents during the past century brought about the development of surgical techniques of extraction, and consequently, dental repulsion became widely practiced. The technical problems and the high incidence of complications associated with dental repulsion, such as dental or osseous sequestra and oro-antral fistula, reported in major studies,^{7,8} stimulated development of an alternative surgical technique of extraction, namely extraction through a buccotomy, which was reported to be associated with a lower incidence of complications than was extraction by repulsion.^{9,10} The technique of extraction by buccotomy was found by many to be technically complicated, necessitated that the horse be anesthetized, and not without complication, such as iatrogenic damage to branches of the dorsal buccal nerve or to the parotid salivary duct.¹¹ Because of complications associated with extraction by repulsion and by buccotomy, extraction *per os* again became the technique of extraction preferred by most practitioners and remains so today.

Extraction *per os*, originally described by Merillat (1906),¹² is associated with a low incidence of complications and is more economical than is extraction by repulsion or by buccotomy.^{7,13} The ease of the technique has been enhanced by the evolution of better instruments, development of more effective sedatives and analgesic drugs, and more widespread use of regional analgesia of dental structures.

Restraining a horse for extracting a cheek tooth *per os*

Although a small proportion of nervous or fractious horses must be anesthetized for extraction of a tooth *per os*, the procedure can usually be performed with the horse sedated. Extracting a cheek tooth with the horse sedated, rather than anesthetized, offers considerable advantages because of the costs and risks associated with anesthetizing a horse.



Fig. 20.14 This horse is sedated, and its head supported in a sling prior to dental extraction.

Extraction *per os* should not be attempted, however, with the horse conscious if the horse's temperament puts the horse or personnel at risk of injury.

Extracting a tooth *per os* with the horse standing is best performed with the horse restrained in stocks, with its head supported in a rigid halter or head-stand (Fig. 20.14). Extracting a cheek tooth constitutes a major surgical procedure, especially when the horse is young, and effective sedation and good analgesia are prerequisites for a successful outcome. (See Ch. 15.) A tooth can be extracted successfully without the use of regional analgesia,⁷ but administering the appropriate regional nerve block greatly improves the ease of the extraction *per os* and reduces the time required to perform the procedure and the quantity of sedation that must be administered.¹⁴ Administering a nerve block, even when extraction is performed with the horse anesthetized, allows the procedure to be performed with the horse in a lighter plane of anesthesia.

Selecting a horse for extracting a cheek tooth *per os*

Teeth with a short reserve crown and those with weakened periodontal attachments caused by advanced periodontal disease can be extracted *per os* without difficulty, but extracting a tooth with a long reserve crown and little periodontal destruction presents a challenge. O'Connor (1942) observed that 'to extract a molar tooth from a sound alveolus in a young horse is almost an impossible task.'¹⁵ However, by using modern techniques, sedatives and analgesic drugs, the appropriate regional nerve block, and appropriate instrumentation, difficulties of extraction *per os* are no longer insurmountable.

Extracting the most caudal cheek teeth (i.e., Triadan 010s and 011s) is technically more difficult because the caudal aspect of the mouth cannot be opened wide, impairing accurate placement of instruments on these teeth. Extraction of teeth with long reserve crowns is hindered by the narrow confines of the caudal aspect of the mouth and interference from the opposing dental arcade.

A fractured cheek tooth can sometimes be extracted orally if the parent fragment is sufficiently large that it can be grasped with an instrument, but many fractured teeth need not be extracted if apical infection is not clinically evident. A fractured tooth, most commonly the maxillary 1st molar (Triadan 09),⁷ is commonly composed of a parasagittal, lateral slab fragment, which nearly always can be removed without difficulty, and a larger, non-displaced, stable, parent fragment, that need not be removed, provided that the two exposed pulps have been sealed off, and clinical signs of apical infection are not present.

Although a diseased maxillary tooth responsible for causing secondary bacterial sinusitis can be extracted *per os*, lavage of the affected sinuses is often necessary after the tooth has been extracted, and if the sinuses contain inspissated exudate, an osteoplastic flap must be created to remove the exudate. (See Ch. 19.)

Technique of extracting a cheek tooth *per os*

The techniques of oral extraction described below are slight modifications of those first described by O'Connor (1942)¹⁵ and Guard (1951).¹⁶ The horse is sedated, and the appropriate regional nerve block is administered using mepivacaine or bupivacaine. Which of these two local anesthetic agents is used depends on the anticipated duration of the procedure. The horse should receive a broad-spectrum, antimicrobial drug and a non-steroidal, anti-inflammatory drug before the procedure. The speculum is inserted into the mouth and opened sufficiently to allow visualization and digital palpation of the dental arcades so that the tooth to be removed can be identified. The veterinary surgeon must have good access to the oral cavity so that the bulky instrumentation required to extract a tooth can be manipulated. A bright head-light is necessary to illuminate the mouth so that instruments can be placed accurately.

The gingiva on the buccal and palatal or lingual aspects of the affected tooth is elevated from the tooth using a right-angled, flat-bladed, dental pick or a small periodontal elevator (Fig. 20.15). The jaws of a molar separator (Fig. 20.16) are placed into the interproximal space rostral and then caudal to the affected tooth to strain the tooth's rostral and caudal periodontal attachments (Fig. 20.17). The jaws are held in place for approximately 5 minutes at each site. When extracting a 3rd premolar (Triadan 07), the molar separator should not be applied with great force between the 2nd and 3rd premolars (Triadan 06 and 07) to avoid inadvertent damage to the periodontal attachment of the 2nd premolar (Triadan 06). Similarly, when removing the 2nd molar (Triadan 010), the molar separator should not be applied with great force between the 2nd and 3rd molars (Triadan 010 and 011). Aggressive use of the molar separator is unnecessary and increases the risk of inadvertently loosening a healthy tooth or fracturing the crown of the affected tooth or that of an adjacent tooth.

After the gingiva has been elevated and the molar separator used, the molar extractor is placed on the tooth to be extracted (Fig. 20.18). Because cheek teeth vary in size and configuration between horses and according to their location within the oral cavity, a variety of molar extractors of different sizes should be available to ensure that the

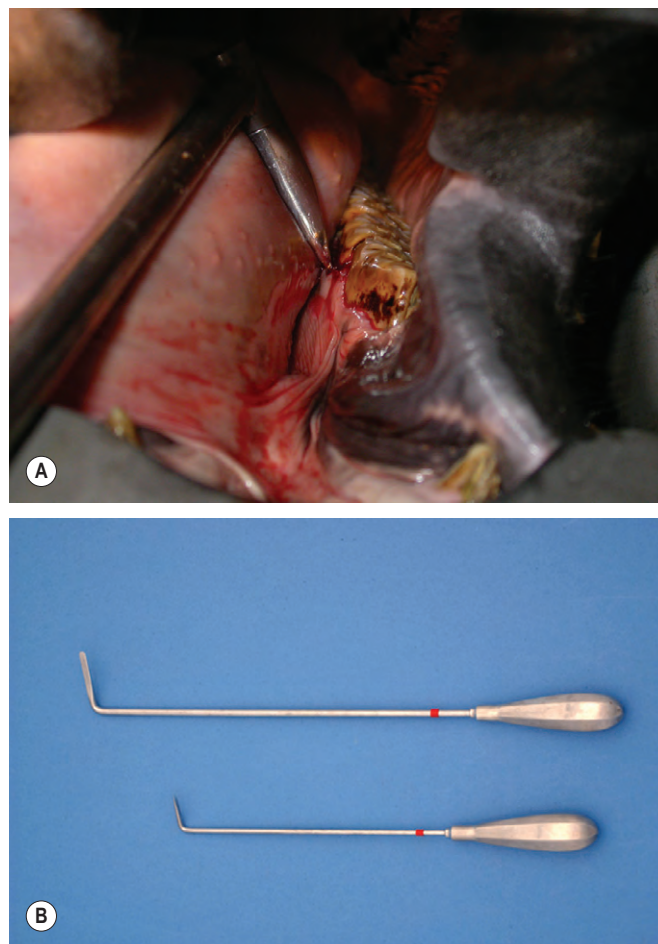


Fig. 20.15 Flat-bladed periodontal elevators are used to elevate the gingival and periodontal attachments from the buccal and lingual aspects of the tooth.



Fig. 20.16 Molar spreaders with varied head designs achieve different degrees of separation.

extractor fits the tooth to which it is applied (Fig. 20.19). Mandibular cheek teeth are narrower than their maxillary counterparts, and therefore require an extractor with a narrower space between the jaws when the handles are closed. Good instrument-tooth contact is essential, and to achieve



Fig. 20.17 Molar separators are used to strain the periodontium on the rostral and caudal aspects of the tooth, as shown in this cadaver specimen.

this contact, the extractor should have a high-quality, box hinge and finely machined, toothed jaws. After the extractor is applied, the oral cavity should be inspected visually to ensure that the correct tooth has been grasped and that the jaws of the extractor do not overlap onto an adjacent tooth. The handles of the extractor are fixed using the locking mechanism found on some extractors, a rubber bandage, or adhesive tape (Figs 20.20 & 20.21).

The handles of the extractors are moved with slow, low-amplitude, horizontal, to-and-fro oscillations along the longitudinal axis of the cheek tooth. The tooth should be inspected visually during the first few oscillations to ensure that the extractor has maintained its grip on the tooth and that the tooth is moving slightly. Incorrect or loose placement of the extractor can result in attrition of the clinical crown, causing the crown to become rounded and impossible to grip. Torsional movement along the axis of the extractor's handles early in the procedure can result in fracture of the clinical crown and should be avoided. The amplitude of the oscillations is increased, but only slightly, as the tooth loosens. Excessive force or attempts to oscillate the extractors in a wide arc can result in shearing of the clinical crown before periodontal attachments of the reserve crown are disrupted. The elasticity of the bony alveolus is slight, and so the arc of movement must also remain slight.

When the periodontal attachments are loosened, a distinctive 'squelching' sound can be heard, and the resistance to movement of the extractor decreases. The squelching sound is frequently accompanied by foamy hemorrhage around the gingival margin (Fig. 20.22). In addition to disrupting the periodontal ligament, the repetitive movement of the tooth may stretch the alveolus, facilitating extraction of the tooth (J. Easley, personal communication). Hundreds of oscillations, sometimes taking an hour or more to perform, may be required before the periodontium is disrupted sufficiently to allow the tooth to be extracted.

After the tooth feels loose enough to be extracted, a dental fulcrum (Fig. 20.23A) appropriate to the size of the

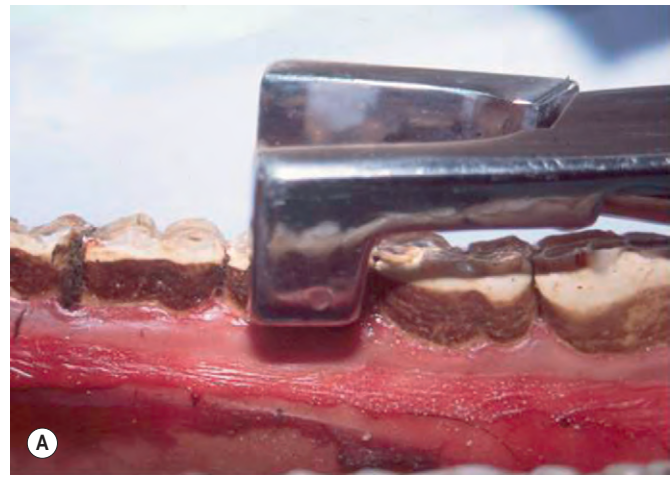


Fig. 20.18 The molar extractor selected to best contact the clinical crown is applied to the tooth, ensuring that it does not overlap onto an adjacent tooth.

extractors is advanced along the occlusal surface of the arcade until it lies between the box hinge of the extractor and the occlusal surface of the cheek tooth rostral to the tooth being extracted (Fig. 20.23B). The mechanical advantage provided by the fulcrum is maximized by advancing the fulcrum as far caudally as possible along the row of cheek teeth. While keeping the molar extractors firmly gripped on the affected tooth, steady, firm pressure is applied to the handles so that the tooth is levered from the alveolus over the fulcrum in a straight line, along its natural pathway of eruption (Fig. 20.24). After the tooth has been partially extracted, re-grasping a more apical portion of the tooth with the extractors may be necessary to extract the rest of the tooth. Axial twisting of the extracting forceps should be avoided until the tooth has been totally freed from periodontal attachments. Re-directing the clinical crown axially, after the tooth has been partially extracted, may be necessary to avoid impingement of the tooth by the opposing arcade (Fig. 20.25). Loosening a 2nd or 3rd molar (Triadan 010 or 011) of a young horse (i.e., <7 years old) can be particularly



Fig. 20.19 A variety of molar extractors of different sizes should be available to ensure that the extractor fits the tooth to which it is applied.

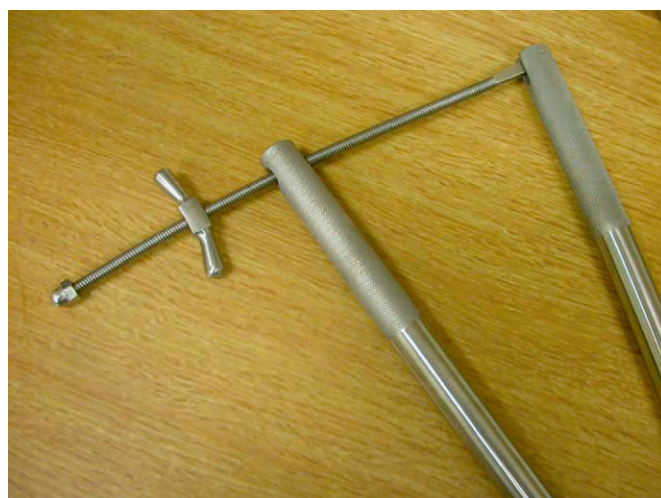


Fig. 20.20 A self-locking mechanism can be found on some molar extractors.

frustrating, due, at least in part, to the tooth's oblique, caudally angled reserve crown. The crown of such a tooth may need to be reduced with a burr, while partially extracted, so that it can be manipulated from the alveolus without it being impinged by the opposite arcade. Sectioning a cheek tooth so that it can be extracted is rarely necessary, and sectioning a mandibular cheek tooth risks the loss of the apical portion of the sectioned tooth into the alveolus from where its removal, without surgery, is difficult or impossible.

After the tooth is extracted from the alveolus, it is withdrawn from the mouth and inspected, paying close attention to its apical aspect, to ensure that it has been removed in its entirety, which is usually the case. The alveolus should then be carefully palpated for the presence of dental or osseous

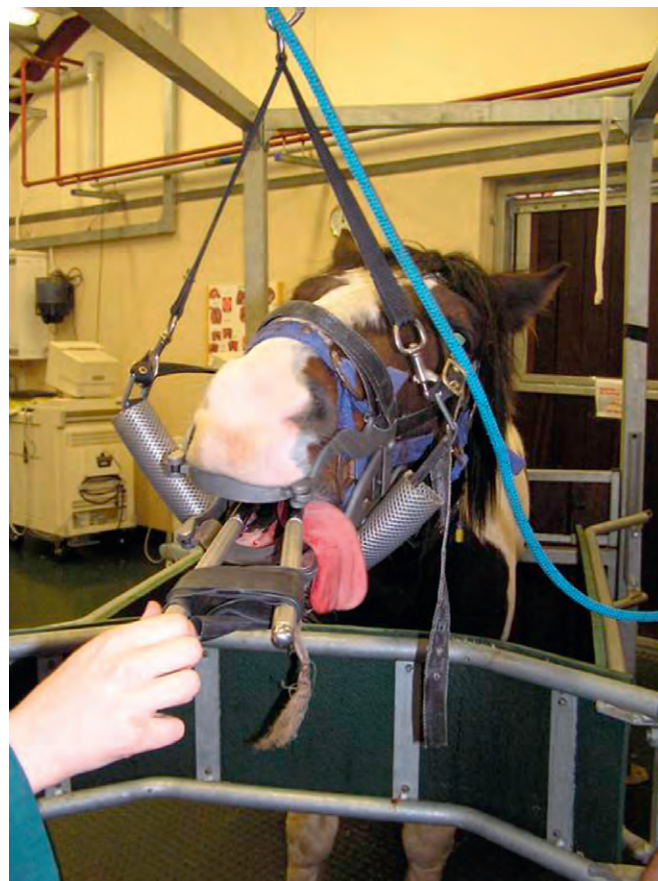


Fig. 20.21 The handles of an extractor can be fixed, after the extractor is correctly positioned, using a rubber band or adhesive tape.

fragments. If fragments are palpated, the alveolus should be carefully curetted, using an angled curette, until the alveolus feels smooth and no osseous or dental fragment remains.

Removing dental fragments can be difficult because often no portion of the tooth is visible supra-gingivally, and because access to the apical aspect of the alveolus, especially one of a young horse, is poor using an oral approach. The dental fragments should be clearly identified on radiographs (Figs 20.26 & 20.27) and then, if possible, elevated *per os* using long, right-angled elevators (Fig. 20.28). After the fragments are loosened, they can be extracted with right-angled forceps; endoscopic guidance greatly facilitates their removal. When dental fragments or fractured teeth cannot be extracted orally, they can be repulsed using a special root fragment punch or Steinmann pin (Figs 20.29–20.31). Radiographic or fluoroscopic guidance may aid the approach to the retained fragments. A 4-mm osteotomy is created over the retained fragment using a Steinmann pin or drill bit, and the Steinmann pin or root fragment punch is inserted into the osteotomy so that it contacts the fragment. If the pin or punch is positioned properly, the fragment can usually be repulsed into the oral cavity with little force. The alveolus is cleaned of debris, using a spoon curette, and irrigated. The

skin incision over the osteotomy is left unsutured to heal by second intention.

A dental fragment can also be extracted with the aid of an elevator inserted through a small buccotomy (Fig. 20.32). The surgical site is identified, a stab incision is created in the

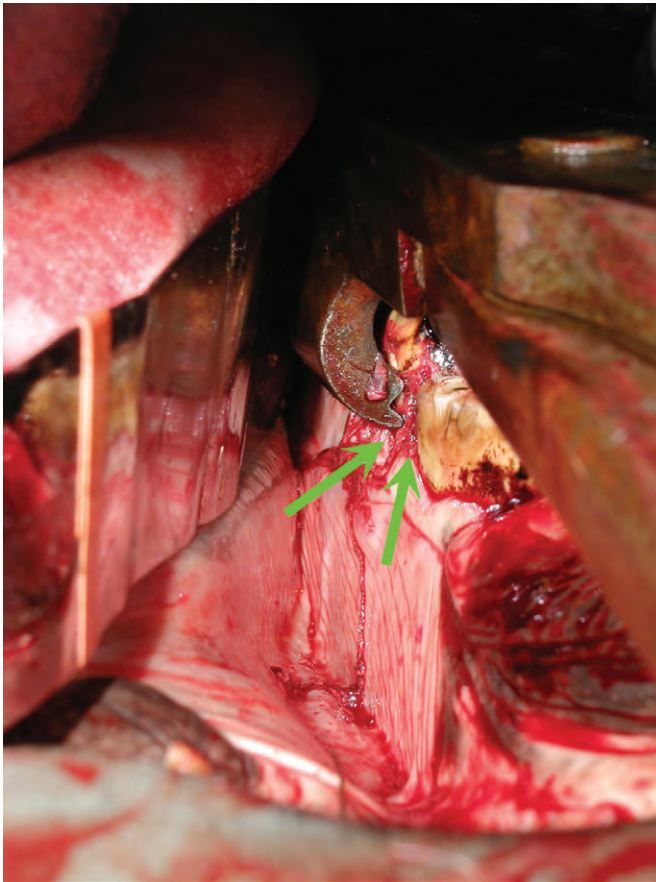


Fig. 20.22 Foamy hemorrhage can be seen around the gingival margin of the tooth when the tooth loosens. This hemorrhage is accompanied by a squelching sound.

cheek at the level of the affected alveolus, and a narrow elevator is inserted into the coronal aspect of the alveolus through the incision to elevate the fragment. After the fragment is elevated, it can be retrieved *per os*. The stab incision is left to heal by second intention. This technique facilitates periodontal elevation of the fragment, allowing it to be extracted without the destructive forces sometimes required when repulsing a dental fragment. Branches of the facial nerve and parotid salivary duct can be damaged using this technique, and the subcutaneous tissues can be inoculated with oral bacteria, resulting in painful cellulitis.

After extracting a cheek tooth, the alveolus can be temporarily loosely packed with polysiloxane putty, dental wax, or a gauze swab impregnated with an antibacterial drug, such as metronidazole paste, but care must be taken to avoid sealing dental or osseous fragments within the alveolus. If dental infection has produced a draining tract, the tract should be irrigated with isotonic saline solution, after removing its epithelial lining with a curette, before the alveolus is packed. The packing is gradually extruded as the alveolus fills with organizing granulation tissue. Infected paranasal sinuses may need to be debrided through an osteoplastic, maxillary or frontonasal flap or through a large trephine hole or lavaged through a catheter inserted into the sinuses through a small trephine hole. If the alveolus communicates with paranasal sinuses, it should be sealed from the sinuses with a material likely to be retained until the communication no longer exists, such as polysiloxane putty or polymethylmethacrylate bone cement.¹⁷

The alveolus should be cleaned and dried with gauze swabs before the plug is inserted. The plug is pressed into the coronal third of the alveolus, while still malleable. The surface of the plug should lie flush with the gingival margins of the alveolus (Fig. 20.33), and formation of a large flange that protrudes from the gingival margin should be avoided (Fig. 20.34). Creating a slight flare on the plug at the gingival margin facilitates removal of the plug when a seal is no longer needed, but an excessively large flare may facilitate early loosening of the plug by the horse's tongue. Filling more than the distal third of the alveolus with the seal may



Fig. 20.23 (A) The dental fulcrum enables the extractor to elevate the tooth from the alveolus. (B) Fulcrums of different thickness may be required so that the force of extraction can be directed appropriately.



Fig. 20.24 After the fulcrum is optimally positioned, the handles of the forceps are pressed on the fulcrum, extracting the tooth from its alveolus.



Fig. 20.25 A caudal cheek tooth of a young horse often has a reserve crown so long that the crown must be directed axially, so that its movement is not impinged by the opposing arcade.

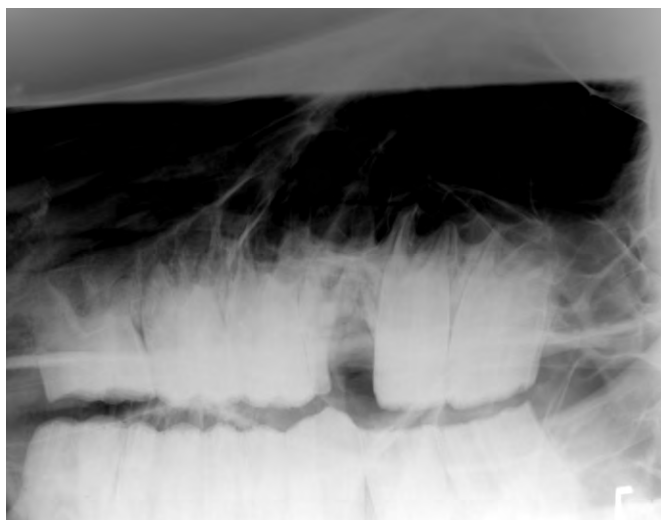


Fig. 20.26 The reserve crown of the 1st maxillary molar (Triadan 09) was fractured during attempted extraction *per os*. The fragments were elevated and retrieved using an oral approach.

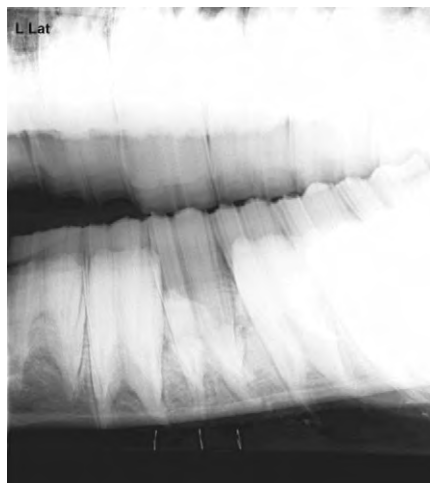


Fig. 20.27 Radiograph showing dental fragment in the apex of a mandibular alveolus. The tooth was fractured during an attempt at extraction *per os*. Dental fragments in the alveolus of a young horse can be difficult to remove, but with careful perioperative imaging to ensure accuracy of the placement of the punch, the fragment can be repulsed into the oral cavity with the horse sedated after desensitizing the affected region with a regional nerve block.

result in delayed healing of the alveolus, and filling the entire alveolus of a maxillary molar is likely to result in formation of an oro-antral fistula.

Care of the horse after extracting a cheek tooth *per os*

Horses require only minimal aftercare after a tooth has been successfully extracted *per os*. The horse should receive a non-steroidal, anti-inflammatory drug for 24–72 hours to provide analgesia, and feeding a soft or soaked feed for a few days postoperatively may be indicated. Lavaging the paranasal sinuses daily or twice daily may be necessary if the horse suffers from dental sinusitis. The alveolus should be inspected digitally, after the seal is removed, usually at 12–14 days, to detect if alveolar sequestra have formed. After a tooth has been removed, that portion of the arcade that opposes the empty alveolus erupts faster and without attrition from mastication (Fig. 20.35). Consequently, the opposing arcade should be rasped frequently (e.g., biannually) to avoid development of ‘step-mouth’. Teeth caudal and rostral to the empty alveolus drift toward that alveolus, but development of diastemata caudal to the empty alveolus is apparently rare.¹⁸

Complications of extracting a cheek tooth *per os*

Complications from dental extraction *per os* are rare.⁷ In one survey, 93% of horses that underwent dental extraction *per os* had no complications. Nevertheless, serious problems can occur. Fracture of the tooth may result in retention of the tooth's apical portion, necessitating its removal by repulsion. A tooth can easily be fractured during its extraction if incorrect technique is used or if the tooth is fragile because of advanced caries, and incorrect placement of instruments



Fig. 20.28 (A) Root elevators and picks of various sizes and shapes are required to elevate root fragments. (B) Dental fragment forceps with long jaws to facilitate extraction of dental fragments.

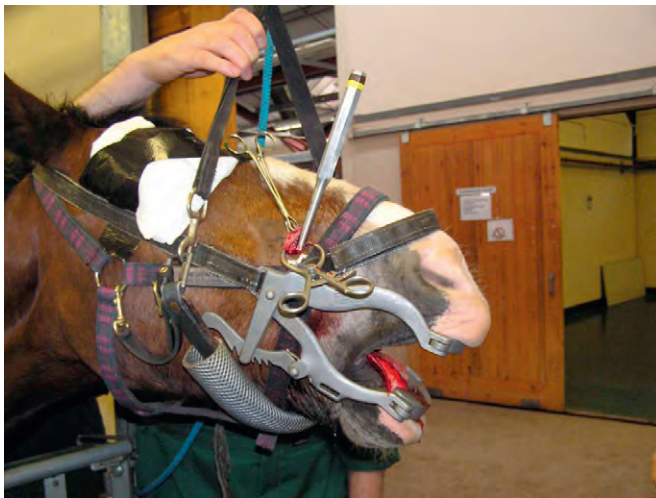


Fig. 20.29 If a fractured root cannot be retrieved using a root elevator, it can be repulsed into the mouth using a Steinmann pin or small punch inserted through a small osteotomy created over the apex of the alveolus.



Fig. 20.31 Fragment of a tooth retained at the apex of the alveolus. The tooth was fractured during an attempt at extraction *per os* and was extracted retrograde using a Steinmann pin.



Fig. 20.30 A small Steinmann pin is in position to repulse a dental fragment into the oral cavity. The pin was positioned using radiographic guidance.



Fig. 20.32 A dental fragment can be extracted by inserting an elevator into the alveolus through a small buccotomy.



Fig. 20.33 The plug, which is pressed into the coronal third of the alveolus, should lie flush with the gingival margins of the alveolus. Large flanges should be avoided.

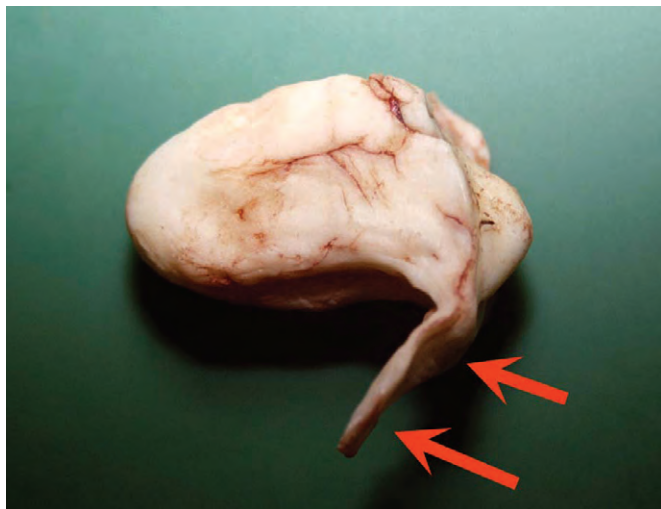


Fig. 20.34 Care must be taken when molding the plug to avoid excessively large flares, which may cause discomfort and may facilitate premature loss of the plug.

can result in damage to a healthy, adjacent tooth.⁷ Applying excessive forces while loosening a tooth can result in fracture of the jaw, especially when extracting a caudal mandibular tooth from a young horse. An ill-fitting alveolar seal can be lost prematurely, resulting in impaction of feed within the alveolus or, if the alveolus communicates with a maxillary sinus (i.e., Triadan 108–111, 208–211), an oro-antral fistula. A loose alveolar seal may allow feed to become trapped between the seal and the alveolus, causing discomfort.

Dental fragments may prevent the alveolus from healing and should be removed at the time of extraction. Occasionally, a portion of the alveolar bone becomes devitalized and subsequently sequestered after extraction, possibly as a result of microfracture that occurred during extraction. These sequestra develop after the tooth has been extracted and are not visible during intra-operative radiographic examination of the alveolus. The sequestered bone results in failure of the

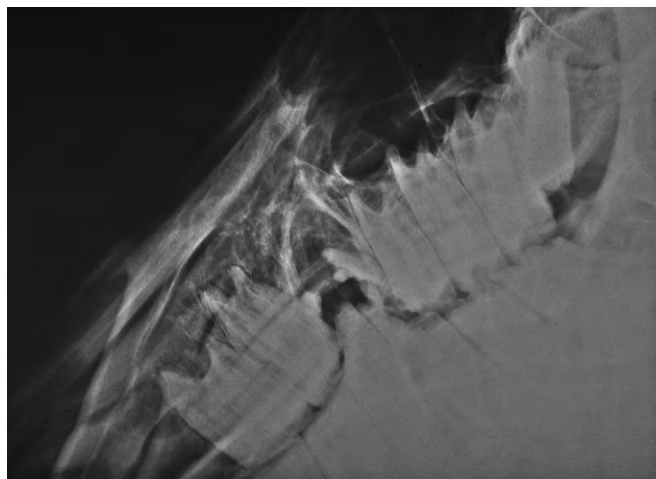


Fig. 20.35 A portion of the right mandibular 4th premolar (Triadan 408) and a portion of the right mandibular 1st molar (Triadan 409) have erupted into the vacant alveolus of the 4th premolar (Triadan 208). After a tooth has been removed, that portion of the arcade that opposes the vacant alveolus erupts faster and without attrition. The opposing arcade should be rasped biannually to avoid this complication. Note the unerupted supernumery maxillary molar (Triadan 12).

alveolus to heal and often causes pain and swelling of soft tissue surrounding the alveolus. The sequestered bone is best removed by curetting the alveolus, which is performed most easily between 2 and 6 weeks after the tooth was extracted. Sequestra may be less likely to form if the alveolus is allowed to fill with clotted blood after the tooth has been extracted.

Persistent, purulent nasal discharge after one or more of the ipsilateral caudal four maxillary cheek teeth have been removed could indicate the presence of an oro-antral fistula, usually the result of osseous or dental sequestra within the alveolus that cause failure of the alveolus to heal. The affected horse commonly has inspissated exudate or feed trapped within the paranasal sinuses. Persistent discharge of purulent exudate and feed from a naris after one or more of the ipsilateral maxillary premolars has been extracted could indicate the present of an oro-nasal fistula. A horse with an oro-antral or oro-nasal fistula is treated by sealing the oral aspect of the affected alveolus with an acrylic plug (Fig. 20.36), a mucoperiosteal flap, or a transposed muscle belly after dental or osseous fragments are removed from the alveolus by curettage and irrigation, and after feed and exudate have been removed from the paranasal sinuses. (See Ch. 19.)

Extracting a tooth *per os* is preferred to surgical techniques of removing a tooth because it can usually be accomplished with the horse standing, has a low incidence of complications, and the horse recovers rapidly. When extraction *per os* is unsuccessful, subsequent removal of the tooth by repulsion or by buccotomy is greatly facilitated because attempts at extraction *per os* weaken the periodontal attachments, thus reducing the enormous forces needed to remove the tooth.

Extracting a cheek tooth using a surgical approach

Surgical removal of teeth usually involves either a retrograde (i.e., via the apex) approach or creation of a mucoperiosteal



Fig. 20.36 Persistent discharge of feed and purulent exudate from a naris after one or more of the ipsilateral maxillary premolars has been extracted could indicate the presence of an oro-nasal fistula. This horse was treated for an oro-nasal fistula by occluding the oral aspect of the fistula with an acrylic plug.

flap with a partial alveolar osteotomy to expose the reserve crown of the tooth. Retrograde removal of a tooth by repulsion became fashionable during the late 19th and early 20th centuries, when general anesthesia of the horse became possible, and the technique has changed little since this time. Complications associated with retrograde removal of a tooth by repulsion resulted in the development of an alternative surgical technique for removal, the buccotomy approach, which entails exposing the reserve crown of the tooth by removing its lateral alveolar wall through an incision into the oral cavity and then removing the tooth after dividing it into segments.

Technique of extracting a cheek tooth by repulsion

Repulsion of diseased teeth remains a commonly performed surgical procedure in equine practice despite the widely reported, high incidence of complications associated with it and its mechanical inefficiency. Regardless of what surgical technique of exodontia is used (i.e., repulsion or extraction via buccotomy), the tooth's periodontium must be disrupted to avoid damage to surrounding alveolar bone, and therefore, attempting to disrupt some of the periodontium, using extraction forceps *per os*, before embarking on a surgical course of dental extraction is prudent. Disrupting some of the periodontal ligament greatly reduces the time of surgery and the likelihood of collateral tissue damage that can occur when the tooth is repulsed.

To repulse a tooth, the tooth's apex must be exposed to allow correct alignment of the dental punch on the apex of the tooth so that force can be delivered along the natural eruption pathway of the tooth. The apex of a cheek tooth is exposed by creating an osteotomy in the overlying mandible or maxillary bone, created using a trephine, drill bit, oscillating bone saw, or chisel (or osteotome). The apex of the tooth can also be exposed through a frontonasal or maxillary



Fig. 20.37 The clinical crown of the first cheek tooth (i.e., 2nd premolar; Triadan 06) is about one-third longer in a rostral to caudal plane than is the clinical crown of the other five cheek teeth in that arcade.

osteoplastic flap if it resides completely within the maxillary sinuses (i.e., the maxillary molars, Triadan 209–211 and 309–311). The osteotomy must be created precisely over the tooth's apex to avoid damage to an adjacent, healthy tooth. The location of the apex varies according to the tooth involved and the age of the horse.

The optimum site of exposure can be identified using several techniques, one of which is to first locate the clinical crown of the diseased tooth and then, by knowing the inclination and length of the tooth, to estimate the location of the tooth's apex. Using this technique, the clinical crown of the diseased tooth, including its mesial and distal contact surfaces, is identified by sight during oral examination. The contact surface of two contiguous teeth is recognized by a palpable depression at the gingival sulcus. (N.B. The clinical crown of the first cheek tooth, i.e., 2nd premolar, Triadan 06, is about one-third longer in a rostral to caudal plane than is the clinical crown of the other five cheek teeth in that row; Fig. 20.37). After the clinical crown has been identified, the location of the apex of the tooth to be removed must be estimated. Its location can be estimated by placing one of two identical dental picks, held in contact at the handles, into the mouth so that its tip rests buccal to the center of the diseased tooth. The other pick is placed adjacent and parallel to the first pick but on the outside of the cheek to demarcate the site of the center of the clinical crown of the affected tooth on the buccal skin.¹⁹

To expose the apex of a mandibular or maxillary 2nd (i.e., Triadan 06) or 3rd (i.e., Triadan 07) premolar, the center of the osteotomy should be on a line perpendicular to the occlusal surface of the arcade at the center of the clinical crown, regardless of the age of the horse (Fig. 20.38).²⁰ The reserve crowns of the mandibular and maxillary 4th premolars (i.e., Triadan 08) and that of all the mandibular and maxillary molars (i.e., Triadan 09–11) curve caudally, in a coronal to apical direction until the horse is about 8 or 9 years old,²¹ and so, to expose the apex of one of these teeth in horses less than 8 or 9 years old, the center of the osteotomy should be approximately level with the caudal contact surface of that tooth, on a plane perpendicular to the occlusal surface of the dental arcade.^{20,21} For horses older than

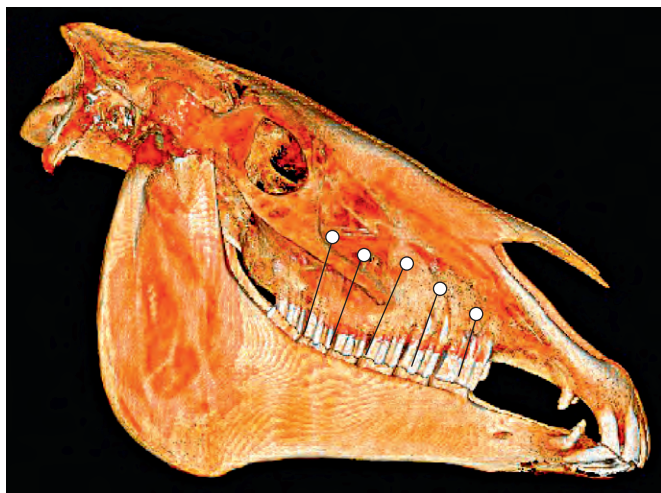


Fig. 20.38 The center of the osteotomy to expose the apex of a mandibular or maxillary 2nd (Triadan 06) or 3rd (Triadan 07) premolar should be on a line perpendicular to the occlusal surface of the arcade at the center of the clinical crown, regardless of the age of the horse. To expose the apex of a mandibular and maxillary 4th premolar (Triadan 08) or that of a mandibular and maxillary molar (Triadan 09–11) of a horse less than 8 or 9 years old, the center of the osteotomy should be approximately level with the caudal contact surface of that tooth, on a plane perpendicular to the occlusal surface of the dental arcade. (Image is courtesy of Luis Velazquez, University of Mexico.)



Fig. 20.39 The proper site for osteotomy can be identified radiographically by placing radio-opaque markers, such as skin staples, in the region estimated to be near the tooth's apex.

9 years, the center of the osteotomy created to expose the apex of any cheek tooth should be approximately level with the center of that tooth, on a plane perpendicular to the occlusal surface of the dental arcade.

Rather than approximating the location of the tooth's apex, using the guidelines described above, the exact site of the apex of the diseased tooth can be identified radiographically by placing radio-opaque markers, such as skin staples, in the region estimated to be near the tooth's apex (Fig. 20.39) or by placing a blunt metallic probe into a discharging tract at the tooth's apex.²² The primary X-ray beam must be approximately perpendicular to the longitudinal and transverse axes of the head because even slight deviation of the beam from a plane perpendicular to these axes markedly distorts the image, which could result in parallax distortion

and inaccurate identification of the site for osteotomy. To see the interproximal dental spaces, the X-ray beam can be deviated slightly rostrally or caudally from perpendicular to the longitudinal axis of the head so that the beam is aligned perpendicular to arcades. Multiple views should be taken until the precise position for the surgical approach is identified with confidence. (See Ch. 13, Dental imaging, for more detail.)

Although a tooth can be repelled with the horse sedated and the surgical site desensitized using regional anesthesia, a cheek tooth is usually repulsed with the horse anesthetized. When extraction is to be performed with the horse anesthetized, a cuffed endotracheal or nasotracheal tube should be inserted into the trachea to prevent inhalation of fluid. The tube should be large enough to permit adequate ventilation, but small enough to provide sufficient space to allow extraction of the tooth. The horse is placed in lateral recumbency with the affected side of the head uppermost. The horse is administered a broad-spectrum antimicrobial drug and a non-steroidal, anti-inflammatory drug before surgery. Anesthetizing the arcade of the affected tooth with a regional nerve block after the horse is anesthetized allows surgery to be performed with the horse in a lighter plane of anesthesia and provides analgesia during the immediate postoperative period (see Ch. 15). A full-mouth speculum (e.g., a Guenther or Bodamer oral speculum) is inserted to provide safe access to the oral cavity. After the horse is anesthetized, but before it is prepared for surgery, the gingiva should be separated from the buccal and lingual or palatine aspects of the tooth to the cortex of the alveolar rim of the tooth to be removed using a long-handled, right-angled periodontal elevator, so that as the tooth is repulsed, the gingiva is not avulsed (Fig. 20.15).

The maxillary or mandibular bone overlying the apex of the tooth can be exposed for osteotomy through a straight, longitudinal skin incision, approximately 5–7 cm long, or through a dorsally or ventrally directed cutaneous flap. A cutaneous flap must be sutured after the tooth is repulsed, but a straight incision can be left unsutured to heal by second intention. Because of the contaminated nature of the surgery, one of us (WHT) prefers to leave the incision unsutured. A straight skin incision extends through the periosteum, which is reflected, using a periosteal elevator, to expose bone for trephination. The curvilinear or rectangular incision of a cutaneous flap extends through the subcutaneous tissue, and after elevating the cutaneous flap, a straight, longitudinal incision is created in the subcutaneous tissue and periosteum, which are then reflected. Reflecting periosteum, rather than removing it, avoids damage to nerves and vessels that overly it, and because the periosteum is spared, healing of the osteotomy proceeds more rapidly.

When exposing bone overlying the apex of the mandibular 1st molar (i.e., Triadan 309 or 409), care should be taken to avoid damaging the facial artery and vein and the parotid salivary duct, which cross the lateral surface of the mandible along the rostral border of the masseter muscle close to the site of osteotomy (Fig. 20.40). Reflecting these structures away from the site of trephination may be necessary. When exposing bone overlying the apex of a maxillary premolar (i.e., Triadan 106–108 or 206–208), care should be taken to avoid damaging the infraorbital nerve and facial artery and vein, which lie in close proximity to the site of osteotomy.



Fig. 20.40 Computed tomographic image of a head showing the facial artery and vein and salivary duct that course along the rostral border of the masseter muscle. (Image is courtesy of Luis Velazquez, University of Mexico.)

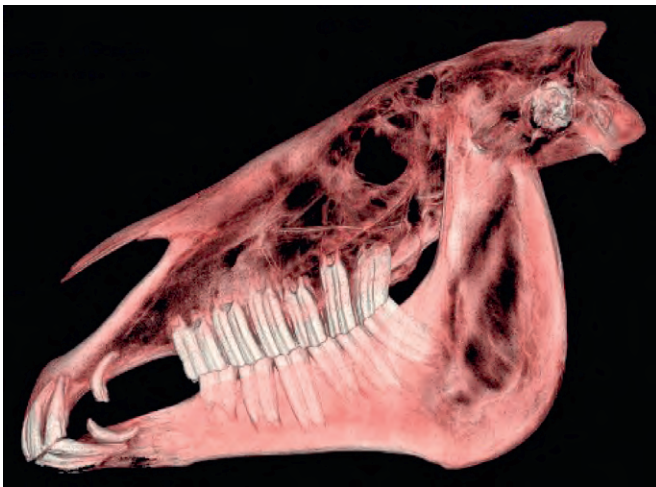


Fig. 20.41 Computed tomographic image of a head showing the relationship between the paranasal sinuses and the maxillary molars (Triadan 109–111 and 209–211). (Image is courtesy of Luis Velazquez, University of Mexico.)

The apex of any one of the three maxillary premolars is exposed by removing the external lamina of the maxilla overlying it, usually with a trephine. The apices of the maxillary molars (i.e., Triadan 109–111 or 209–211) reside within the paranasal sinuses (Fig. 20.41) and can be exposed through a trephine hole or through an osteoplastic flap into the paranasal sinuses.

Regardless of where the apex of the tooth is determined to reside, the osteotomy created to expose the apex of a maxillary cheek tooth should be ventral to an imaginary line that marks the course of the nasolacrimal duct. This duct courses between the medial canthus of the eye and a point slightly dorsal and rostral to the infraorbital foramen.²³ The dorsal aspect of the osteotomy should be close to this line if the horse is less than 8 years old because the cheek teeth of horses less than 8 years old have undergone little attrition of length.²⁴ To avoid damaging the infraorbital nerve when removing a maxillary 3rd (Triadan 107 or 207) or 4th (Triadan 108 or 208) premolar, the dorsal aspect of the osteotomy should be ventral to the infraorbital foramen. The



Fig. 20.42 Trephines and bits suitable for creating an osteotomy for repulsion.

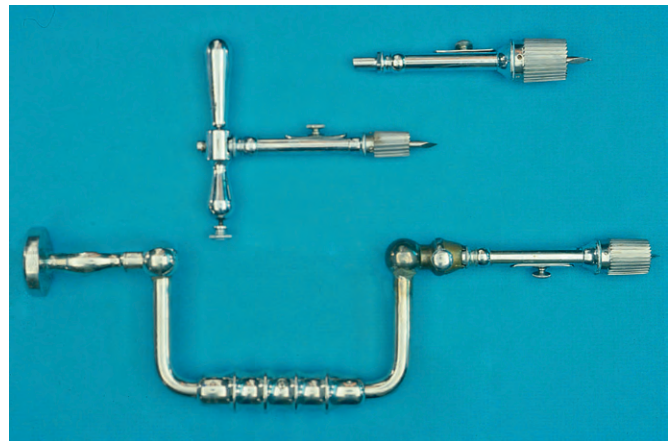


Fig. 20.43 Galt trephine. The brace attached to one of these trephines decreases the amount of effort required to create the osteotomy.

ventral aspect of the osteotomy should be close to the facial crest if the horse is old. The mandibular cheek teeth of young horses often extend to the ventral border of the mandible, and so, if the horse is young, the ventral aspect of the osteotomy should also extend to the ventral border of the mandible.

After incising and reflecting the periosteum, the apex of the tooth is exposed through an osteotomy, which is commonly created using a 1.5- to 2-cm ($\frac{1}{2}$ - to $\frac{3}{4}$ -inch) diameter Galt trephine or a 0.95-cm to 2.7-cm ($\frac{3}{8}$ - to $\frac{1}{2}$ -in) drill bit rotated in a hand drill or by hand (Figs 20.42 & Fig. 20.43). To create a hole in the external lamina of a maxilla or the mandible with a trephine, the center-pin of the trephine is extended and seated perpendicular to the exposed bone and the trephine is rotated to and fro until the center-pin penetrates the bone and the barrel of the trephine cuts a circular groove in the bone. The center-pin is retracted or removed, and the circular osteotomy is continued until the disc of bone is completely transected. If the transected disc of bone is not removed with the barrel of the trephine, it can be pried from its attachments with a bone gouge.

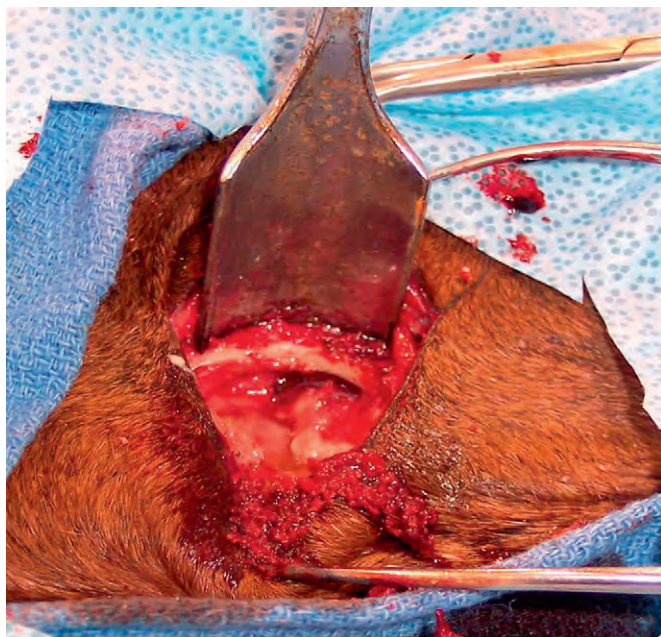


Fig. 20.44 A bone gouge and mallet can be used to enlarge the trephine hole.

The apex of the tooth is completely exposed by removing overlying cancellous alveolar bone with a bone curette. To avoid damaging an adjacent, healthy tooth, the entire apex of the tooth should be exposed, and both contact surfaces of the diseased tooth identified before the tooth is repulsed into the oral cavity. Suction is helpful at this point in the procedure to aid visibility, which is usually obscured by constant capillary bleeding. If the trephine hole has not adequately exposed the apex of the tooth, the hole can be enlarged using a bone rongeur or a bone gouge and mallet (Fig. 20.44). The apical end of the tooth can be transected perpendicular to the long axis of the tooth, using a chisel (or osteotome) and a mallet or a diamond cutting wheel, and removed to provide a flat platform for a punch to be seated and aligned properly along the long axis of the tooth. Transecting and removing the apex of the tooth may also provide space to maneuver the punch into proper alignment.

The maxillary 1st or 2nd molar (i.e., Triadan 09 or 010) can be removed through a trephine hole created into the paranasal sinuses over the apex of the tooth. To repulse the maxillary 1st molar (i.e., Triadan 109 or 209), which is the most commonly diseased maxillary tooth, the trephine hole is usually centered at a point midway between the rostral end of the facial crest and a point on the facial crest at the level of the medial canthus of the eye, 1 cm ventral to an imaginary line drawn between the infraorbital foramen and the medial canthus of the eye.

To remove the 2nd maxillary molar (i.e., Triadan 110 or 210), the trephine hole is centered more caudally over the caudal maxillary sinus, rostroventral to the ventral orbital rim; but the site varies between horses and is affected by the age of the horse. Selection of the optimal site for trephination should be guided by radiographic examination. One author has suggested an approach to the 2nd maxillary molar that involves creating three trephine holes (i.e., the

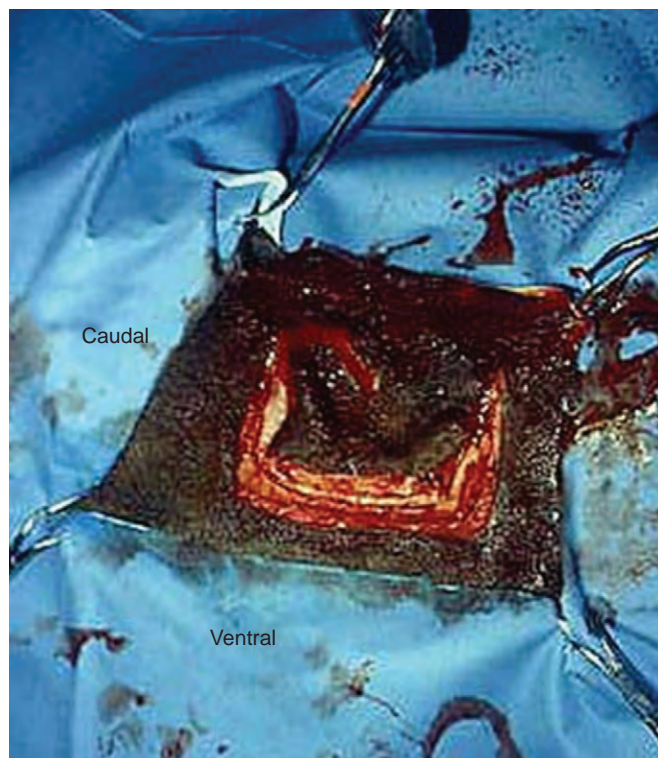


Fig. 20.45 This figure shows the creation of an osteoplastic maxillary flap, using an oscillating saw, to expose the rostral and caudal maxillary sinuses. The apices of maxillary molars can be exposed through this flap. The 1st or 2nd maxillary molars (i.e., Triadan 109 or 110 or 209 or 210) or sometimes the 3rd maxillary molar (Triadan 111 or 211) are repulsed into the oral cavity using this approach.

triple trephine technique).³ Using this approach, one hole is created dorsomedial to the medial canthus of eye for placement of the punch on the apex of the tooth. A second hole, created ventrorostral to the medial canthus, allows the punch to be guided onto the apex of the tooth and allows the alveolus to be inspected postoperatively. The third hole, created at the angle formed by the orbit and the facial crest provides a portal for placing a catheter into the caudal maxillary sinus for postoperative lavage of the paranasal sinuses. Alternatively, reasonable access to the 2nd maxillary molar of mature horses (i.e., >8 years old) can be gained through either a maxillary or frontonasal, osteoplastic flap.

To create a dorsally hinged, osteoplastic maxillary flap, a three-sided incision through the skin, subcutis, and periosteum is created within the confines of the boundaries of the rostral and caudal maxillary sinus (Fig. 20.45). A technique to create and close a maxillary osteoplastic flap is described in detail in Chapter 19, Basic equine orthodontics and maxillofacial surgery. The osteoplastic, maxillary flap provides the operator opportunity to visually examine a large extent of the paranasal sinuses and permits manipulation of dental instruments within the sinuses.

A disadvantage to creating an osteoplastic maxillary flap, rather than a trephine hole, to repulse a maxillary molar, is that unless the flap is reopened, access to the apical aspect of the alveolus is no longer accessible to monitor healing of the alveolus or to curette the alveolus, should the need arise. Access to the apical aspect of the alveolus after surgery is



Fig. 20.46 Aligning a dental punch along the eruption path of a tooth is made much easier using an off-set, or double-curved, punch. Note that the shanks are different in length. Two or three off-set punches, each with a different length of shaft, may be required to completely repulse a tooth.

easier if the apex of the tooth was accessed through a trephine hole, provided that the skin over the hole is left unsutured to heal by second intention. If the cutaneous incision over the trephine hole was sutured or stapled, the incision can be re-opened to inspect the apical end of the alveolus and then re-sutured or stapled when access is no longer required. If the apex of the tooth was accessed through an osteoplastic flap into the sinuses, the apical end of the alveolus can be inspected endoscopically through the trephine hole created to provide a port for lavage of the sinuses.

Because the apex of the maxillary 3rd molar (i.e., Triadan 111 or 211) lies beneath the eye, it must be exposed either through a trephine hole in the frontal bone or through a frontonasal, osteoplastic flap. The punch is inserted through the frontomaxillary aperture into the caudal maxillary sinus to engage the apex of this tooth, which lies ventral to the infraorbital canal. Aligning a dental punch along the eruption path of a maxillary 3rd molar is difficult because of the tooth's position below the orbit and its caudal curvature. Using an off-set (i.e., a double-curved) punch (Fig. 20.46) to repel the maxillary 3rd molar may be helpful because obtaining proper alignment between the punch and tooth without damaging the infraorbital canal is often difficult using a straight or curved punch.

Removing a mandibular 2nd (Triadan 310 or 410) or 3rd (Triadan 311 or 411) molar is particularly difficult because the bone over the apices of these teeth is covered by the masseter muscle and because the apices of these teeth are distant from the ventral border of the mandible, even in young horses. To remove one of these teeth, and sometimes the mandibular 1st molar (i.e., Triadan 309 or 409), the ventral aponeurosis of the masseter muscle is incised so that the muscle can be reflected dorsally to expose the underlying thin lateral lamina of the mandible overlying the apex of the tooth (Fig. 20.47).

To elevate the masseter muscle, skin is incised along the ventrocaudal border of the mandible, ventral to the masseter muscle, from the angle of the mandible rostrally, taking care to avoid the parotid salivary duct and facial artery and vein where they cross the mandible at the rostral aspect of the

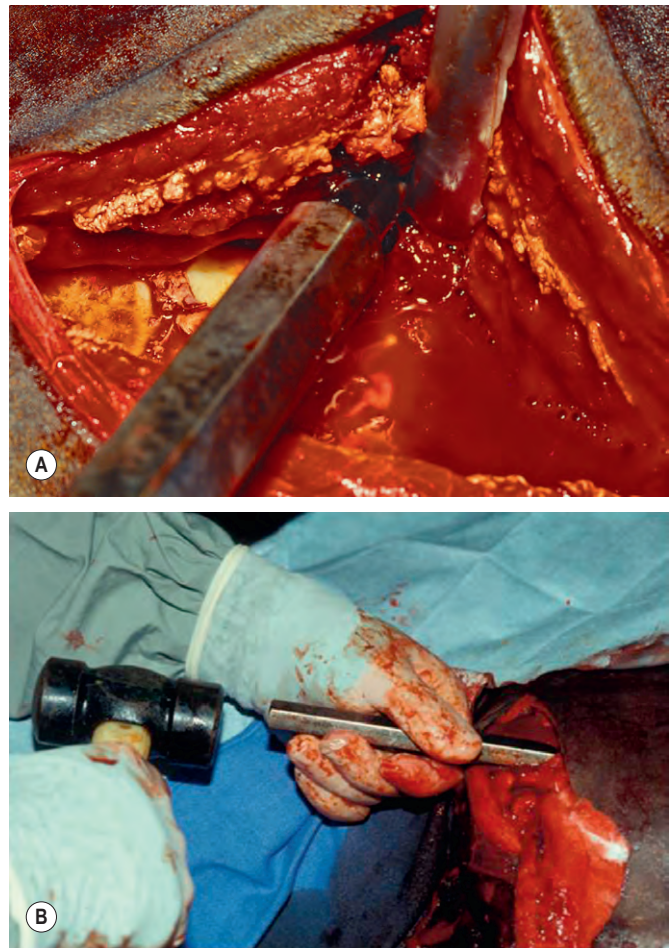


Fig. 20.47 To remove the 2nd and 3rd mandibular molar (Triadan 310, 311, 410, or 411) and sometimes the mandibular 1st molar (i.e., Triadan 309 or 409), the masseter muscle is reflected dorsally to expose the underlying lateral lamina of the mandible overlying the apex of the tooth. (A) The ventral aponeurosis of the masseter muscle has been incised. (B) After creating a trephine hole over the apex of the tooth to be removed, the punch is aligned along the long axis of that tooth.

masseter muscle. The incision is extended through the insertion of the muscle, and the muscle and the periosteum to which the muscle is attached are elevated to expose the external lamina of the mandible. The site for osteotomy to expose the apex of the diseased tooth is then located using one of the methods described above.

The lateral plate of bone overlying the apex of the 3rd mandibular molar (i.e., Triadan 311 or 411) can also be exposed through an incision in the masseter muscle. Using this approach, the skin is incised obliquely in a plane that extends from the occlusal surface of the tooth to the angle of the mandible.²⁵ This incision exposes the fibers of the masseter muscle, which traverse the lateral lamina of the mandible in the same dorsorostral to ventrocaudal direction as the skin incision. The masseter muscle is split bluntly, along the course of its fibers, being careful not to damage the dorsal and ventral buccal branches of the facial nerve that lie superficial to the muscle. The thin bone over the apex of the 2nd molar (i.e., Triadan 210 or 410) can be exposed through a similar but more rostral incision. Aligning the



Fig. 20.48 When repulsing a tooth into the oral cavity, the punch should be aligned in the direction of the tooth's path of eruption. Confirming the position of the punch radiographically ensures that the punch is properly aligned. The punch seen in this radiographic projection is in close alignment with the longitudinal axis of the tooth.

punch along the long axis of the tooth, so that the tooth can be repulsed efficiently, is difficult using this approach, especially if the masseter muscle is thick.

After the apex of a diseased cheek tooth has been exposed using techniques described above, the tooth is repulsed into the oral cavity by striking a dental punch applied to the apex of the tooth and aligned in the direction of the tooth's path of eruption. Confirming the position of the punch radiographically ensures that the punch is properly aligned (Fig. 20.48). Failure to align the punch correctly may result in damage to a neighboring tooth, the palatine bone, if the tooth is maxillary, or to the internal or external lamina of the mandible, if the tooth is mandibular. When the punch is aligned obliquely to the long axis of the tooth, more force is required to repulse the tooth because the periodontium is not disrupted as efficiently as when the punch is properly aligned. The extra force required is more likely to result in bony or dental sequestra. Because the reserve crowns of the cheek teeth curve axially in a coronal to apical direction, and because the mandibular and infraorbital nerves lie slightly medial to the center of the teeth, applying the punch slightly lateral to the central axis of the tooth reduces the risk of damaging these nerves.

An off-set punch is often easier to properly align than is a straight or angled punch, but two or three off-set punches, each with a different length of shaft, may be required to completely repulse the tooth (Fig. 20.46). Continuing to strike to the punch with the mallet after the horizontal arm of the off-set punch has contacted bone at the margin of the trephine hole results in damage to the bone and is ineffective in repulsing the tooth. Off-set punches with shafts of various lengths can be made by a farrier for little expense.

By inserting a hand in the horse's mouth and palpating the clinical crown of the affected tooth, the operator or a non-scrubbed assistant can determine if the punch is

properly aligned and seated on the tooth intended to be removed. The operator or assistant can detect percussion transmitted through the tooth and movement of the tooth. Striking the punch when it is in contact with the tooth produces a higher pitched sound than when the punch is struck when in contact with bone. A better feel for proper alignment of the punch can be appreciated if the operator with the hand in the mouth also controls the alignment of the punch with his or her other hand while a trustworthy, second operator wields the mallet. Numerous, vigorous blows with the mallet are usually required to dislodge the tooth from its alveolar and gingival attachments, but when movement of the tooth can be felt with the hand in the mouth, the force of the blows to the punch is decreased. A long tooth of a young horse, especially a tooth located caudally on the arcade, must often be deviated axially with an extractor as the tooth is repulsed so that the tooth does not become impinged by the opposing arcade. Transverse sectioning of a partially repulsed tooth to facilitate its repulsion is awkward to perform, risks creating subgingival dental fragments, and despite being widely advocated by others, is seldom or never necessary. Wedged teeth can usually be maneuvered after minor profiling using a rotary burr. After the tooth has been repulsed, the operator whose hand was in the mouth must re-glove before proceeding with the surgery.

Because the tooth is usually fragmented while being repulsed, it should be examined to determine if pieces are missing, and the alveolus should be inspected visually and digitally for osseous and dental fragments. Dental fragments still attached to the alveolus may be difficult to detect. The tooth of a young horse is more brittle than that of an old horse, and therefore, is more likely to be fragmented. After the alveolus is curetted, irrigated, suctioned, and dried, it should be examined radiographically to detect osseous or dental fragments that may remain within it. A ventrodorsal radiographic projection of the alveolus, obtained with the cassette in a sterile sleeve, provides a good view of the vacated alveolus (Fig. 20.49). Pulling the mandible laterally may allow a view of the entire vacated alveolus unobstructed by superimposition of teeth in the opposing arcade.

The alveolus is sealed from the oral side using polysiloxane putty (President Putty, Henry Schein, UK), bone wax, polymethacrylate (PMMA) bone cement (Palacos R, Glaxo-SmithKline), gutta percha,³ or plaster of Paris,²⁶ to prevent feed and saliva from contaminating the alveolus. Plugs of PMMA provide the best long-term security against alveolar contamination, but PMMA has the disadvantage of generating considerable heat as it sets.

The plug should fill no more than the coronal third of the alveolus so that the bulk of the alveolus is able to fill first with a blood clot and then with granulation tissue. The plug should not extend past the gingiva. A plug that protrudes past the gingiva is prone to loosening by the tongue or from mastication. Care should be taken when molding a plug to the alveolus to avoid forming sharp projections that can cause discomfort to the horse by traumatizing the tongue or gingiva. Care should be taken to ensure that the plug's apical end is narrower than its coronal end and that the plug fits tightly within the alveolus. The plug should be examined after the horse recovers from anesthesia, using digital palpation, to ensure that it is seated tightly within the alveolus. A

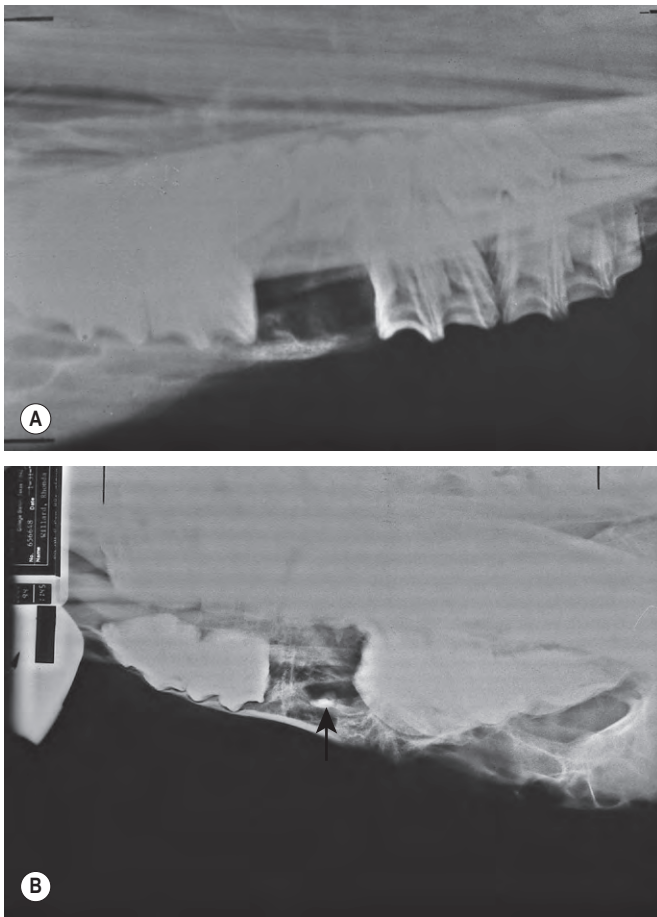


Fig. 20.49 (A) A ventrodorsal radiographic projection of the alveolus provides a good view of the alveolus. Pulling the mandible laterally may allow a view of the entire vacated alveolus unobstructed by superimposition of teeth in the opposing arcade. (B) A dorsoventral radiographic projection showing a dental fragment within an alveolus (arrow points to fragment).

loose plug should be removed with extraction forceps and replaced after irrigating debris from the alveolus; this can usually be accomplished with the horse sedated and its mouth held open with an oral speculum.

Because the alveoli of old horses are shallow, care must be taken to avoid over-packing the alveolus. The pack placed into the alveolus of an old horse should be shallow so that granulation tissue can form unimpeded through most of the alveolus. An alveolar plug that extends into a maxillary sinus results in a persistent, oro-antral fistula (see Ch.19). Over-packing the alveolus can be avoided by packing gauze swabs into the apical end of the alveolus, and then removing them after the alveolar plug, placed orally into the coronal aspect of the alveolus, has set. If the skin incision is to be sutured, it should be sutured only after the plug has been inserted, so that the depth to which the plug has been packed in the alveolus can be determined accurately. If the incision is to be left open, rolled gauze impregnated with a dilute solution of povidone-iodine can be packed concertina fashion into the apical aspect of the alveolus, prior to inserting the plug orally into the coronal aspect of the alveolus. The gauze can then be gradually removed over the next 4–5 days.

If maintaining the implant in the alveolus is likely to be difficult, such as when the tooth removed was the 1st cheek tooth (2nd premolar, Triadan 06), the plug can be molded around a small section of screen to which a loop of stainless steel wire has been attached (Fig. 20.50).²⁰ The ends of the wire loop are inserted through the oral entrance to the alveolus and exited through the osteotomy and a cutaneous stab incision created adjacent to the site of osteotomy. The plug and screen embedded within it are pulled into the oral aspect of the alveolus, and the ends of the wire loop are secured under tension over a gauze roll. The gauze roll is changed when it becomes soiled.

A straight skin incision over the site of osteotomy is often left open to heal by second intention because contamination of the surgical site with oral pathogens is inevitable. Leaving the incision unsutured allows the alveolus to be inspected and loose, osseous or dental debris retained within the alveolus to be easily retrieved. The alveolus can be irrigated and monitored daily, visually and by palpation, for healing through the open incision. The leakage of saliva contaminated with ingesta from the incision or escape of fluid into the mouth during irrigation of the alveolus indicates that the alveolar plug should be replaced. Packing gauze swabs into the skin incision until the alveolus has filled with granulation tissue, usually at 2–3 weeks, prevents gross contamination of the surgery site from the environment.

If the skin incision at the osteotomy is to be sutured, the surgical site should be irrigated vigorously. If the likelihood of infection at the surgical site is high, a drain can be placed into the depths of the wound and exited through another small incision. The subcutaneous tissue is sutured with absorbable monofilament suture, and the skin incision is apposed with non-absorbable suture or staples (Fig. 20.51). The inelastic periosteum holds sutures poorly and need not be sutured. Gauze swabs are placed over the incision and held in place with sutures or with adhesive, elastic tape applied to the head in a figure-of-eight fashion to minimize swelling at the surgical site and to prevent the horse from mutilating the site. The head is generally left bandaged for at least 5 days. If the incision was sutured, it should be inspected periodically for signs of subcutaneous infection. The incision should be opened if signs of infection, such as drainage through the incision, are observed.

Granulation tissue surrounding the plug epithelializes within several weeks. The plug may eventually be lost spontaneously, but if not, it can be removed, usually at about 2 weeks after surgery, with the horse sedated (Fig. 20.52). The portion of alveolus occupied by the plug fills completely with granulation tissue after the plug is removed. Permanent retention of a plug is desirable only when the horse is at increased risk of developing an oro-antral fistula. If the plug is attached to a wire loop, both the plug and the wire must be removed.

If the paranasal sinuses are to be lavaged after a maxillary molar has been repulsed, a 0.95-cm ($\frac{3}{8}$ -inch) trephine hole, which is large enough to accommodate a 26- or 24-Fr Foley catheter, is created, through a straight cutaneous incision into the conchofrontal or caudal maxillary sinus through a small incision. A trephine hole into the conchofrontal sinus is created 2–3 cm medial to the medial canthus of the eye, and a trephine hole into the caudal maxillary sinus is created, through a straight incision, 1.5 cm ventral

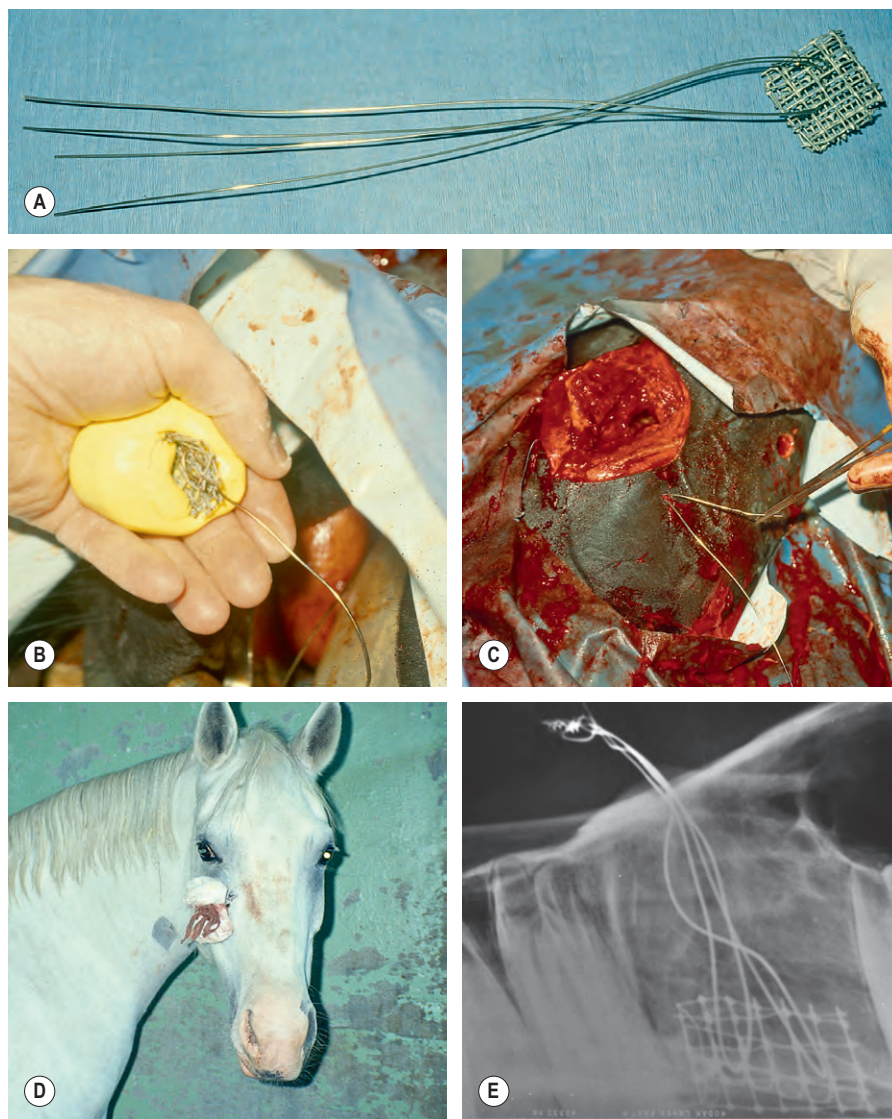


Fig. 20.50 Maintaining the plug in the alveolus is sometimes difficult if the alveolus is that of a 2nd premolar or if 2 teeth adjacent to each other were removed. (A & B) To keep a plug secure in the alveolus, it can be molded around a small section of screen to which a loop of stainless steel wire has been attached. (C) The ends of the wire loop are inserted through the oral entrance to the alveolus, exited through the osteotomy and a cutaneous stab incision, and the acrylic and embedded screen are pulled into the oral aspect of the alveolus. (D) The ends of the wire loop are secured under tension over a gauze roll. (E) Radiograph of a dental arcade showing the implant sealing two alveoli from which the teeth were repulsed.

to the ventral rim of the eye. Warm, isotonic saline solution or a solution of povidone-iodine instilled into the sinuses through the Foley catheter exits the sinuses into the nasal cavity through the nasomaxillary aperture. The sinuses are lavaged for 1–7 days; the frequency and duration for which the sinuses are lavaged depends on the degree to which the sinuses were contaminated. The cutaneous incision over the osseous portal can be sutured or stapled after the catheter is removed, or the incision can be allowed to heal by second intention.

Complications associated with extracting a cheek tooth by repulsion

The owner should be advised that a horse that has lost a cheek tooth requires life-long, prophylactic dental care and should be forewarned that serious complications of dental extraction by repulsion are common and often result in the need for additional surgery. In a report of 220 horses that had undergone surgical removal of a cheek tooth, 165 had undergone extraction by repulsion, and of these, 65 had

complications serious enough to necessitate a second surgery.¹⁰

The most serious complication associated with extracting a cheek tooth by repulsion is unintended damage to other structures, such as adjacent, healthy teeth, the infraorbital or mandibular nerve (Fig. 20.53), and palatine bone (Fig. 20.54) or medial or lateral lamina of the mandible or maxilla (Fig. 20.55). Other complications associated with dental repulsion include early loss of the alveolar plug causing contamination of the alveolus and paranasal sinuses with feed; formation of an oro-antral fistula; damage to the nasolacrimal duct, parotid salivary duct, infraorbital nerve, or palatine artery; and most commonly, a chronic draining tract caused by sequestration of alveolar bone or dental fragments.⁸ The more caudal the tooth, the more likely is the horse to suffer one or more of these serious postoperative complications.¹⁰

The owner should be forewarned that even when the alveolus is determined to be free of bony fragments at the time of surgery, the severe trauma to which the alveolus was subjected when the tooth was repulsed can result in the



Fig. 20.51 The apex of a diseased premolar of this horse was approached through a straight skin incision for repulsion of the tooth into the oral cavity. Because the likelihood of infection at the surgical site is high, the stapled incision should be inspected periodically for signs of subcutaneous infection. The incision should be opened if signs of infection are observed.



Fig. 20.52 The alveolus can be carefully inspected visually and digitally after removing the implant to ensure that it has commenced to granulate. Bone not covered with granulation tissue may be devitalized and sequestered.

formation of osseous sequestra within the alveolus, causing failure of the alveolus to heal. The large concussive forces required to repulse a tooth may create minute alveolar fractures that are not visible during postoperative radiographic examination of the alveolus. These fractures may result in formation of alveolar sequestra in subsequent weeks, leading to resumption of clinical signs of apical dental infection and an alveolus that fails to heal. Bone not covered by granulation tissue encountered when palpating the alveolus 2 to 3 weeks after surgery should be suspected of being devitalized



Fig. 20.53 The horse may mutilate its nose if the infraorbital nerve is damaged.

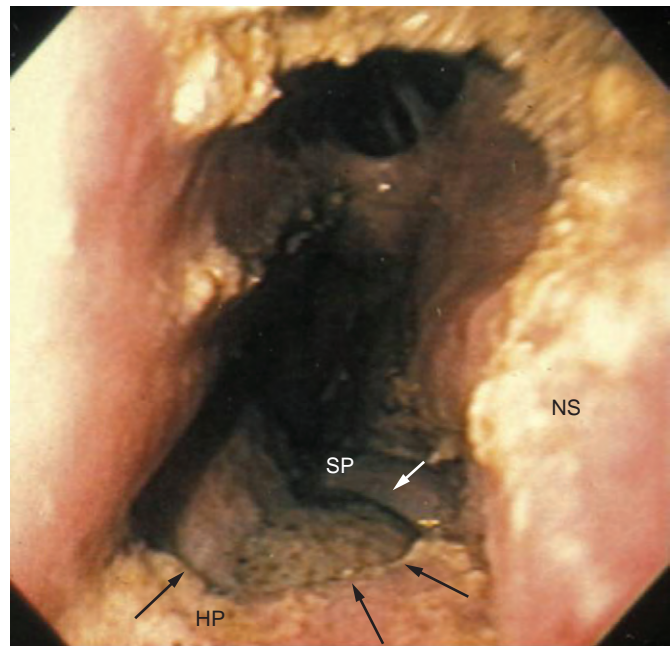


Fig. 20.54 Endoscopic view of the right nasal cavity of a horse after repulsion of a maxillary molar showing a large hole (arrows) in the hard (HP) and soft palates (SP) from injury from the dental punch. The nasal septum (NS) is on the right.

and sequestered. Partially disrupting the periodontium before embarking on repulsion greatly reduces the concussive forces required to repulse the tooth and, therefore, reduces the likelihood of creating osseous sequestra.

Contamination of the alveolus from premature loosening or loss of the implant usually results in nothing more serious than delayed granulation of the alveolus, but if the alveolus is one that communicates with the paranasal sinuses, loss of the implant can result in formation of an epithelialized

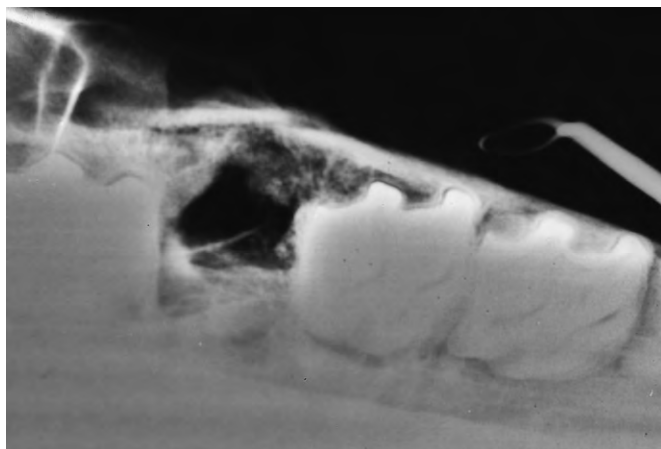


Fig. 20.55 A fracture of the lateral alveolar wall after repulsion of a maxillary tooth is evident on this ventrodorsal radiographic projection.

oro-antral fistula, signs of which include chronic, purulent, nasal discharge.

If clinical signs of apical dental infection fail to resolve after the infected tooth has been repulsed, the alveolus should be examined carefully, radiographically and using a mirror or an endoscope, for the presence of dental or osseous sequestra or an oro-antral fistula. The relationship between a draining tract, the nasal cavity, and the alveolus can sometimes be elucidated by infusing fluorescein dye into the tract and observing for the presence of dye in the nasal or oral cavity. Radiographic examination of the alveolus with a fine radio-opaque probe inserted into a draining tract over the alveolus may help demonstrate the relationship between a discharging tract and a sequestrum. Small sequestra can be removed by curettage using an oral approach or a retrograde approach through the osteotomy.

Extracting a cheek tooth using a horizontal or vertical buccotomy approach

A transalveolar approach to the infected tooth through a horizontal or vertical buccotomy has been used successfully to remove any one of the mandibular or maxillary cheek teeth except the 3rd molar (Triadan 011).^{9,10} The horizontal or vertical buccotomy approach to dental extraction offers the advantages of precision and accuracy and good visualization of the tooth to be removed, which precludes the possibility of iatrogenic damage to unaffected teeth. Exposing the buccal aspect of the tooth permits a more controlled disruption of the periodontal ligament than does repulsion of the tooth, but the procedure must be performed with the horse anesthetized. The lateral aspect of the alveolus of maxillary or mandibular premolars (Triadan 06–08) is accessed through a horizontal incision, and that of the 1st or 2nd mandibular or maxillary molar (Triadan 09 and 010) is accessed through a vertical incision created parallel to the long axis of the tooth.³

The tooth to be removed, using the buccotomy approach, is identified with the assistance of radiography or fluoroscopy, using skin markers, and by locating the interproximal



Fig. 20.56 Vertical buccotomy approach for extracting the right 2nd mandibular molar (Triadan 410). The vertical incision is created caudal to the facial vein and artery and the parotid salivary duct.

space on either side of the tooth to be removed from within the oral cavity. The incision should not be made until the interproximal margins of the tooth to be removed have been positively identified by an unscrubbed assistant whose hand is within the mouth. Placing a small-gauge, hypodermic needle through the skin at each interproximal space helps define the site of incision. For the horizontal buccotomy approach, a curvilinear skin incision, centered over the diseased tooth, is made at the level of the tooth's gingival reflection in the buccal cleft. For the vertical buccotomy approach, the incision is made parallel to the linguofacial artery and vein (Fig. 20.56). By using a vertical incision to extract the 1st or 2nd mandibular molar (Triadan 309, 310, 409 or 410), rather than a horizontal incision, trauma to the linguofacial artery and vein and the parotid salivary duct is avoided. To extract the first mandibular molar (Triadan 309 or 409), the incision lies rostral to the linguofacial artery and vein, and to extract the second mandibular molar (Triadan 310 or 410) the incision lies caudal to the linguofacial artery and vein at the rostral border of the masseter muscle. Retracting the masseter muscle caudally provides a good view of the lateral mandibular cortex overlying the 1st and 2nd mandibular molars (Triadan 309 and 310 or 409 and 410).

During the buccotomy approach, extreme care is taken to avoid damage to the dorsal buccal branch of the facial nerve when removing a maxillary tooth, and to the ventral buccal branch of the facial nerve when removing a mandibular tooth. These branches lie superficial to the musculature. These nerves can be identified and reflected atraumatically from the surgical site (Fig. 20.57). The incision for a maxillary buccotomy is made dorsal to the parotid papilla located at the rostral aspect of the 4th maxillary premolar (Triadan 108 or 208), and the incision for a mandibular buccotomy is made ventral to it. As the dissection to the lateral dental alveolus deepens, the ventral buccal glands and the buccal venous plexus, which is composed of the *labialis communis*, *labialis maxillaris*, and *labialis mandibularis* veins, are

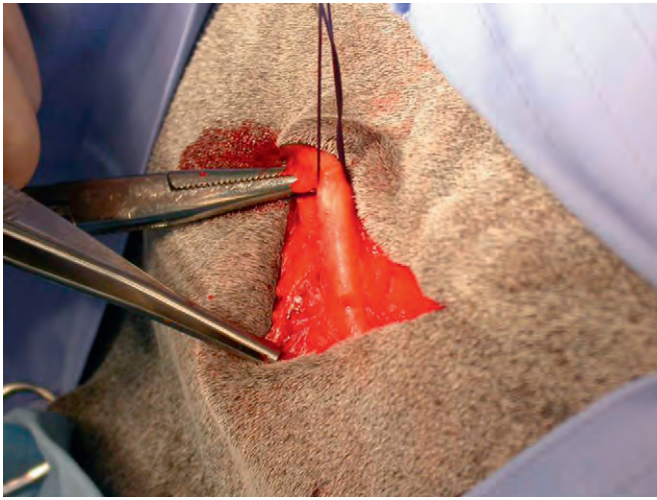


Fig. 20.57 For the buccal approach to dental extraction, vital structures, such as the dorsal or ventral buccal branch of the facial nerve, must be identified and retracted carefully. The suture surrounds the ventral buccal branch of the facial nerve.

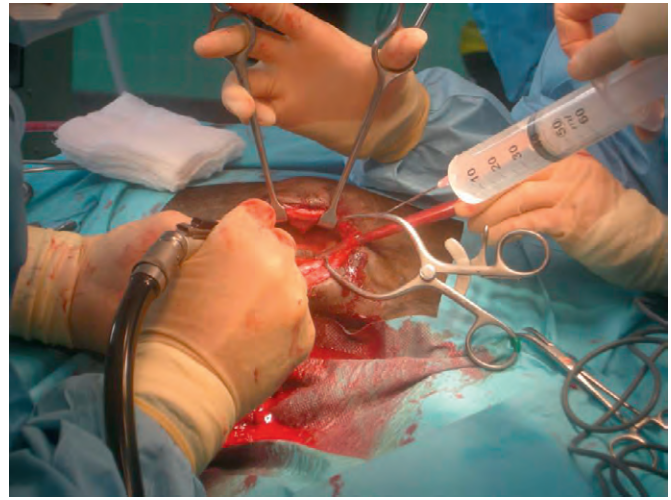


Fig. 20.59 Extraction through a buccotomy. The alveolar bone over the buccal aspect of the cheek tooth is being removed with a burr.

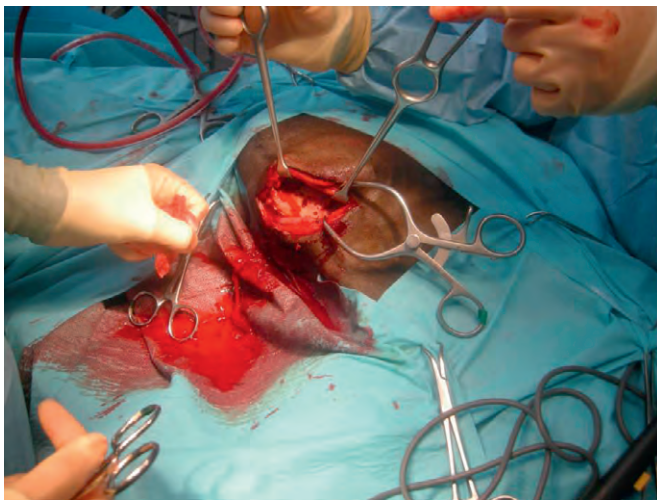


Fig. 20.58 Extraction through a buccotomy. The oral mucosa is incised to expose the buccal alveolar bone.

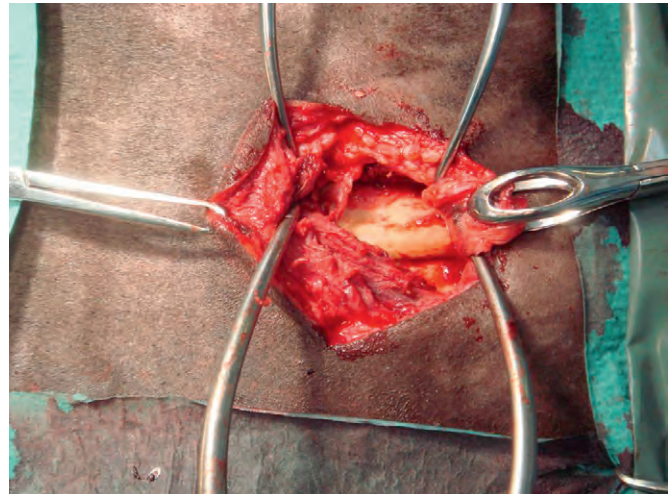


Fig. 20.60 Extraction through a buccotomy. The buccal aspect of the alveolus has been removed, allowing sectioning of the periodontium.

encountered. After dissecting through these structures, paying extreme attention to detail and hemostasis, which is assisted by suction, the tough, oral mucous membrane is encountered. By incising it, the clinical crown of the tooth to be removed is exposed (Fig. 20.58).

A gingival flap is raised on the lateral aspect of the alveolus of the tooth with a periosteal elevator to expose the lateral alveolar cortex of the maxilla or mandible. The periosteum is incised at the center of the tooth, parallel to the long axis of the tooth, and reflected to either side. The buccal alveolar bone that spans the rostral and caudal contact surfaces of the tooth is incised parallel to the long axis of the tooth at the rostral and caudal interproximal margins of the tooth using an oscillating saw, a surgical fissure burr, or a sharp chisel (Fig. 20.59). This plate is elevated and removed using an osteotome or periodontal elevator to expose the buccal

aspect of the reserve crown of the tooth. At least two-thirds of the lateral alveolar wall is removed to completely expose the apical end of the tooth.

The periodontium on the rostral and caudal surfaces of the tooth is disrupted using a fine elevator or curved gouge (Fig. 20.60). Space for extraction can be created by splitting the tooth longitudinally, using a burr. The tooth can also be removed by transecting it transversely with a chisel, in which case, the occlusal fragment is advanced into the oral cavity, where it is removed, to provide access to the apical portion of the tooth, which can then be elevated intact or piecemeal from the alveolus using a gouge or curved periodontal elevator (Fig. 20.61). Radiographic examination at this point in the procedure is necessary only when the surgeon has doubt as to whether the entire tooth has been removed.

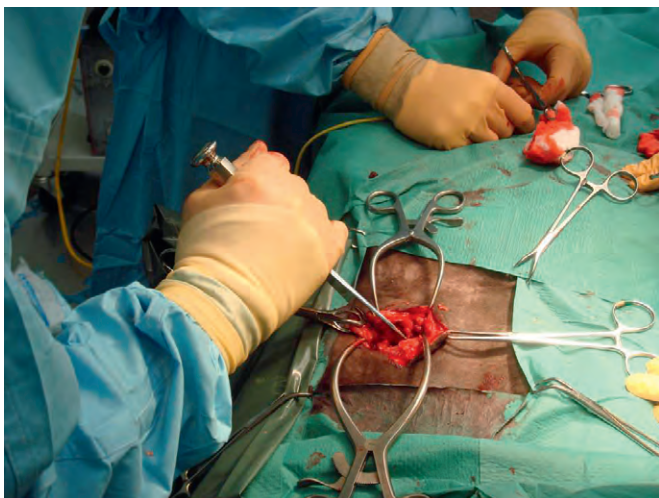


Fig. 20.61 Extraction through a buccotomy. The tooth is being sectioned with a chisel before it is removed.



Fig. 20.63 Extraction through a buccotomy. The oral aspect of the alveolus is sealed with a plug of polysiloxane.

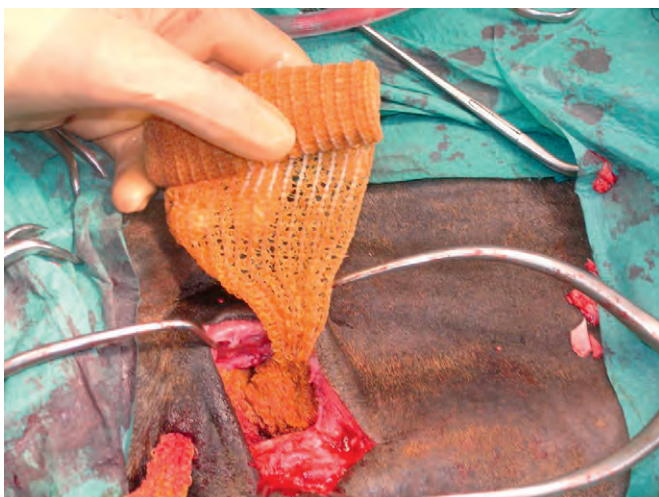


Fig. 20.62 Extraction through a buccotomy. The empty space at the apical aspect of the alveolus is packed with rolled gauze impregnated with a dilute solution of povidone-iodine.



Fig. 20.64 The incision is sutured in three layers, and the end of the rolled gauze is exited through a separate incision.

After the tooth has been removed, the empty alveolus is packed concertina fashion with rolled gauze impregnated with a dilute solution of povidone-iodine (Fig. 20.62). One end of the gauze exits through a stab incision created adjacent to the original incision so that the gauze can be withdrawn a few inches at a time during the next 5–10 days. A plug of acrylic, such as polysiloxane, is placed into the oral aspect of the alveolus over the gauze packing (Fig. 20.63), but because the buccal portion of the alveolus has been removed, this implant often soon loosens. The gingival flap can be sutured but, because of inevitable contamination of the surgery site, is often left to heal by second intention. The buccotomy incision is closed in three layers, using monofilament absorbable suture to close the incision in the oral mucosa and subcutaneous tissue, and non-absorbable suture or staples to close the skin incision (Fig. 20.64).

Complications associated with extracting a cheek tooth using a horizontal or vertical buccotomy approach

The most serious complications associated with extracting a cheek tooth by buccotomy are irreversible, iatrogenic damage to the ventral or dorsal buccal nerve and parotid salivary duct. In one study, only 1 of 44 horses that had undergone removal of a cheek tooth by buccotomy had a complication that necessitated a second surgery.¹⁰ Complications arising from extraction by buccotomy included temporary facial paralysis from trauma to the dorsal buccal branch of the facial nerve (2 horses) and partial wound dehiscence (6 horses). Transection and subsequent anastomosis of the parotid salivary duct was required to access the diseased tooth of 2 horses.

References

1. Blundeville T. The fower chiefyst offices belonging to horsemanshippe. London, 1566
2. Lane JG. A review of dental disorders of the horse, their treatment and possible fresh approaches to management. *Equine Veterinary Education* 1994; 6: 13–21
3. Lane JG. Exodontia: Part 2: surgical extraction of equine molars and premolars (cheek teeth). In: Baker GJ, Easley J, eds. *Equine dentistry*, 2nd ed. Elsevier, Edinburgh, 2005, pp 279–294
4. Shira RB. Principles of exodontia. In: Guralnick WC, ed. *Textbook of Oral Surgery*, Little, Brown and Co, Boston, 1968, p. 79
5. Nickel R, Schummer A, Seifarle E. The anatomy of domestic animals, 2nd edn. Verlag Paul Parey, Berlin and Hamburg, 1979
6. Markham G. Markham's masterpiece. G Conyers, London, 1723
7. Dixon PM, Tremaine WH, Pickles K, et al. Equine dental disease Part 4. A long-term study of 400 cases: apical infections of cheek teeth. *Equine Vet J* 2000; 32: 182–194.
8. Prichard M, Hackett R, Erb H. Long-term outcome of tooth repulsion in horses: a retrospective study of 61 cases. *Vety Surg* 1992; 21: 145–149
9. Evans LH, Tate LP, LaDow CS. Extraction of the equine 4th upper premolar and 1st and 2nd upper molars through a lateral buccotomy. *Proceedings AAEP* 1981; 28: 249–252
10. Lane GJ. Equine dental extraction-Repulsion vs Buccotomy: Techniques and results. *Proceedings World Veterinary Dental Congress, Birmingham*, 1987, pp 135–138
11. Easley J. Equine tooth removal. In: Baker G, Easley J, eds. *Equine dentistry*, eds. WB Saunders, London, 1999, pp 228–229
12. Merillat MA. Equine dentistry and diseases of the mouth. *Veterinary Surgery*, Vol. 1, Alex Eber, Chicago, 1906
13. Tremaine WH. Oral extraction of equine cheek teeth: a Victorian technique revisited. *Proceedings World Veterinary Dental Congress, Birmingham*, 1987, pp 139–143
14. Tremaine WH. Local analgesic techniques for the equine head. *Equine Veterinary Education* 2007; 19: 495–503
15. O'Connor JJ. Operations. In: *Dollar's Veterinary surgery*, 3rd edn. Baillière, Tindall and Cox, London, 1942, pp 250–261
16. Guard WF. Equine operations. In: *Surgical principles and techniques*. WF Guard, Columbus, Ohio, 1951, pp 78–89
17. Dixon PM. Dental extraction and endodontic techniques in horses. *Compendium of Continuing Education for the Practicing Veterinarian* 1997; 19: 628–637
18. Townsend N, Barakzai S. Abstracts of the 17th scientific meeting of the ECVS, *Veterinary Surgery* 2008, 95–98
19. MacDonald MH, Basile T, Wilson WD, et al. Removal of maxillary tooth fragments and root remnants in standing horses. *Proceedings AAEP-Focus on Dentistry* 2006, 148–155
20. Wheat J. Sinus drainage and tooth repulsion in the horse. *Proceedings AAEP* 1973; 19: 171
21. Frank E. *Veterinary surgery*, 7th edn. Burgess, Minneapolis, 1964, pp 156–159
22. Lane J, Gibbs C, Meynink S, et al. Radiographic examination of the facial, nasal and paranasal sinus regions of the horse: I. Indications and procedures in 235 cases. *Equine Vet J* 1987; 19: 466–473
23. Sissons S, Grossman J. The anatomy of the domestic animals, 4th edn. WB Saunders, Philadelphia, 1953, pp 387, 882
24. Mueller P. Equine dental disorders: Cause, diagnosis, and treatment. *Compendium of Continuing Education for the Practicing Veterinarian* 1991; 13: 1451
25. McIlwraith C, Turner A. *Equine surgery: advanced techniques*, 2nd edn. Williams and Wilkins, Philadelphia, 1987, pp 289–292
26. Trostle S, Juzwiak J, Santschi E. How to use antibiotic impregnated plaster of Paris for alveolar packing after tooth removal. *Proceeding AAEP* 2000; 46: 180–181

Dental materials

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Introduction

Throughout recorded equine dental history, exodontia has been the only treatment option for diseased teeth. The goal of equine dentistry is to preserve functional dentition in order to promote the general health, longevity, and productivity of the horse. In an effort to preserve functional dentition, clinicians have begun to apply accepted dental technologies and to adapt dental materials from human and small animal dentistry. This cross-species extrapolation is common in both human and veterinary dentistry since all mammalian dental tissues are similar; however, the equine clinician must understand the differences between brachydont and hypsodont teeth when applying materials designed for use in human teeth.

The purpose of this chapter is to serve as a general resource for equine practitioners to facilitate the incorporation of dental materials into their practice. It includes a basic discussion of dental cements, restorative, endodontic, and periodontal materials, and impression materials. Specific material brand recommendations have been purposely omitted since hundreds of materials are available in each category and since the dentist's preferences are a major factor in the final selection of a specific brand. However, many experienced dentists advise using a single line of materials for each category. The general clinical application steps for each category of materials is presented, but every dental material has unique properties, handling characteristics, and an application protocol based on the ratios of essential components and the addition of proprietary components. To optimize the clinical properties of any material, the manufacturer's instructions for storage, mixing, and application must be followed exactly.

Dental cements

Dental cements are primarily used for bonding prosthetics (*luting agents*) and orthodontic appliances to teeth. Zinc phosphate, zinc oxide eugenol, and polycarboxylate cements are available and still used in dentistry. However, glass ionomer and resin composite cements are primarily used today because of their superior properties and handling

characteristics. To select and apply the appropriate cement, practitioners must be familiar with the bonding mechanism for each material ([Box 21.1](#)). Since luting applications are rarely practiced in equine dentistry, dental cements will be discussed with respect to their use in the other dental disciplines.

Restorative dentistry

Restorative dentistry is the dental discipline concerned with the treatment, repair, and conservation of teeth broken down by trauma or decay. The goals of restorative dentistry include returning the diseased tooth to its original shape and function, preventing breakdown of the remaining tooth structure, protecting the pulp from thermal, mechanical, and bacterial insult, and creating an esthetic tooth appearance. The indications for restorative dentistry include dental decay, resorptive lesions, crown fractures, attrition, congenital anomalies, enamel hypoplasia, and access closure of an endodontically treated tooth.¹ Restorative dentistry can be divided into two sub-disciplines: direct placement restorations and laboratory-assisted restorations (prosthodontics). The scope of this discussion will be limited to direct placement restorations.

Regardless of the disease etiology, the restoration of a tooth includes two equally important procedures: 1) cavity preparation and 2) selection and application of the restorative materials. Treatment planning for any restoration must include radiographic evaluation of the affected tooth and its surrounding tissues. Radiographic evaluation of the diseased tooth includes evaluation of the pulp, the specific location of the lesion, and the depth and extent of the lesion. Radiographic findings consistent with pulp disease would indicate root canal therapy before tooth restoration. The location of the lesion on each specific tooth determines the forces that will be applied to the restoration. Restorations on the occlusal surface of a tooth must be designed to withstand compressive loading and wear, whereas restorations on the apical aspect of the clinical crown might experience tension or bending stresses. *Regardless of the present location of the lesion, all restorations have the potential for eventual occlusal*

Box 21.1 Types of bonding

1. **Mechanical retention:** Non-adhesive bonding where the dental material infiltrates the surface irregularities of the dental tissue and cures to interlock with the dental tissue. **All cements exhibit mechanical bonding.**
 - A. **Macromechanical retention** – involves instrumented undercuts (retention grooves) in the dental tissues (usually dentin). The bonding mechanism with **non-bonded amalgams** and **self-curing resin composites** (Fig. 21.1).
 - B. **Micromechanical retention** – involves surface preparation (acid etching) and the use of bonding agents that microscopically interlock in the enamel porosities (Fig. 21.2), dentinal tubules (Fig. 21.3), and other microscopic surface irregularities. The bonding mechanism with **resin composite** and **resin modified glass ionomer** cements and **light-cured resin composite** and **bonded amalgam** restorations.
2. **Chemical bonding:** **Glass ionomer** and **polycarboxylate cements** form a chemical crystal bond between the carboxyl groups in the polyacid of the cement and the calcium ions of the apatite crystals in the enamel and dentin.

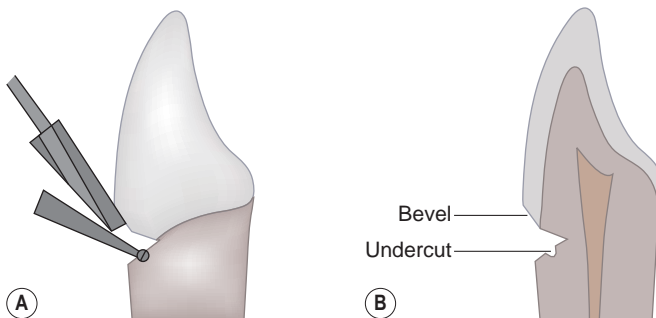


Fig. 21.1 Placement of small retention groove in dentin using a small round burr. (Courtesy of K-J. Söderholm.)

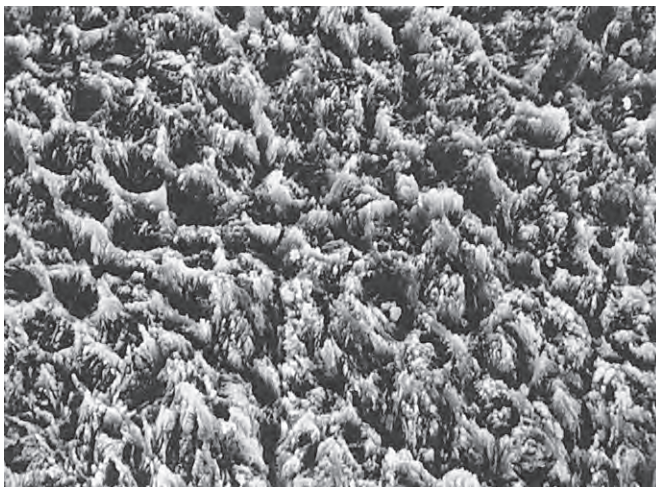


Fig. 21.2 Surface of etched enamel in which the centers of enamel rods have been preferentially dissolved by the phosphoric acid. (Courtesy of K-J. Söderholm.)

wear due to hypsodontic tooth eruption; therefore, the strength and wear resistance of restorative materials must be considered during material selection. The depth and extent of the lesion must be evaluated to determine the dental tissues involved in the lesion, as well as the proper size and shape of the

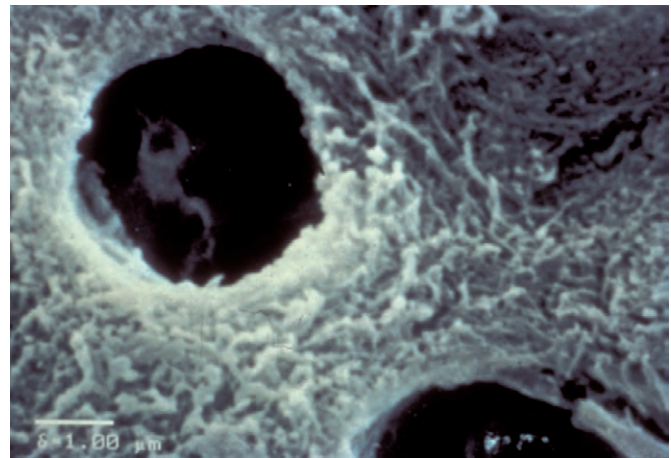


Fig. 21.3 Demineralized dentin that has been kept moist. The collagen structure is preserved. (From van Noort R 2002. Introduction to dental materials, 2nd edn. Mosby, St Louis.)

cavity preparation. Consideration of these factors will determine the required properties of the restorative materials needed to fill the cavity.

During treatment planning, the clinician should also try to identify and eliminate the cause of the lesion, especially in traumatic cases. Failure to eliminate the cause often leads to subsequent destruction of the restoration. Finally, a client's esthetic demands may influence the practitioner's choice of the final restorative material and its finish.

Cavity preparation

Cavity preparation is the surgical operation involving the debridement of decayed or diseased dental tissues in order to shape the tooth to receive and retain the restorative material.² Regardless of the etiology or location of the lesion, the operator must adhere to the following principles. First, the cavity must be prepared so that all diseased and damaged dental tissues are removed without weakening the tooth's structure. Inherent in this principle is that as much tooth as possible must be preserved so that the restoration does not compromise the structural integrity of the tooth. Secondly, the cavity is extended to prevent further decay or damage to the restoration. The focus of this extension is the removal of any unsupported or undermined dentin and enamel. To achieve this, the walls of the cavity are formed parallel to the enamel rods, which are usually oriented perpendicular to the tooth surface (Fig. 21.4). Finally, the cavity is configured to facilitate filling, retention, and finishing of the restorative material. This step may include dentinal undercutting for mechanically retained materials and marginal beveling to increase the enamel surface bonding area.³ Advances in modern restorative materials make the necessity of dentinal undercutting debatable.⁴ Since cementum, not enamel, is the peripheral tissue on the crown of equine teeth and since the bonding of restorative materials to cementum has not been studied, the value of marginal beveling of the cavity preparation is also debatable.

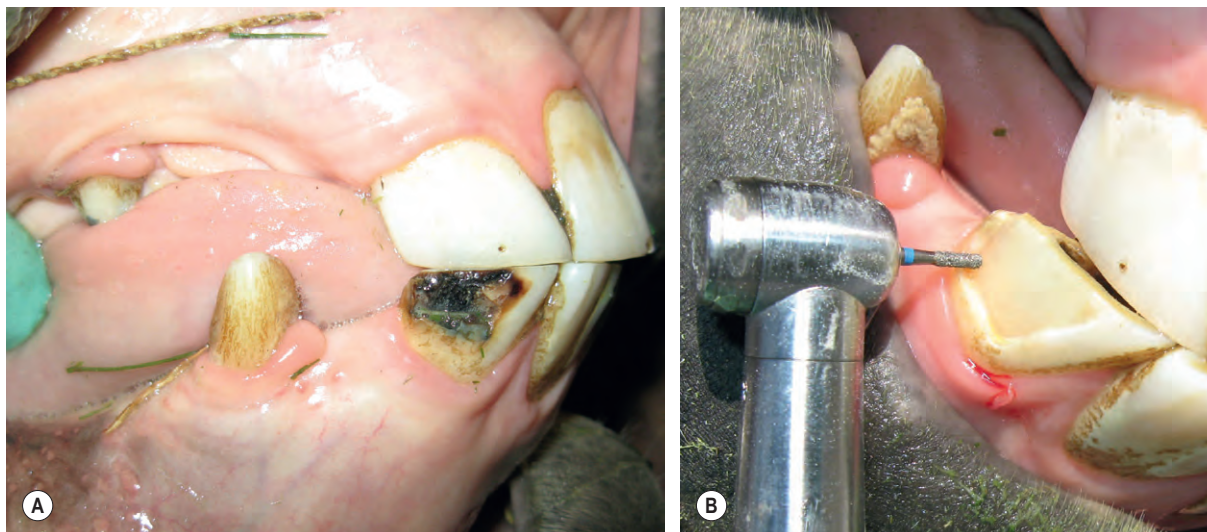


Fig. 21.4 (A) Decay of the mandibular right 3rd incisor (403). (B) Cavity preparation using a diamond burr on a high-speed handpiece. Note that the walls of the preparation are perpendicular to the surface of the tooth. The author elected not to instrument retention grooves (dental undercuts) or marginal beveling since this shallow preparation was designed for a resin composite filling.

Bases and liners

Cavity preparations, in which less than 2 mm of dentin remains between the pulpar wall and the pulp (indirect pulp exposure), require the application of a pulp protecting material.⁵ Cavity varnishes, liners, and bases are used to protect the pulp. *Cavity varnishes* are organic solvent and resin solutions that seal dentinal tubules. They do not prevent acid penetration or thermal conductivity, and are losing popularity since the organic solvent can interfere with the polymerization of resin composites.

Cavity liners are non-irritating materials that are placed in a thin layer to protect the pulp and decrease dentinal sensitivity. They provide no thermal or mechanical protection and are inadequate as a sole protecting medium. Calcium hydroxide (CaOH), the most popular liner, is supplied as a powder or as commercially prepared pastes. The powder can be applied directly into a cavity or mixed into a paste with water, saline, or an anesthetic. The strong alkalinity (pH 12.5 when mixed with saline) of CaOH is bactericidal, neutralizes acids, and induces reparative dentin formation. CaOH dissolves if contaminated with oral fluids and must be covered by another restorative material.

Cavity bases are used in deep cavities to provide structural support for the final restoration and chemical and thermal protection of the pulp. Dental cements are typically used as bases. Reinforced zinc oxide-eugenol (ZOE) cement (Intermediate Restorative Material, IRM)^a has been a historically popular cavity base. This material is losing popularity because eugenol interferes with the bonding of resin composites. ZOE cements have a pH of approximately 7, which is thought to have protective and soothing properties on the pulp. In cases of direct or near pulp exposure, a liner should be used since ZOE cements can cause pulp inflammation. ZOE cements are dispensed as zinc oxide powder and eugenol liquid or as a two paste system. Zinc oxide and

eugenol chemically react to form a chelate. The setting time is accelerated by humidity, elevated temperature, and increasing the powder-to-liquid ratio. Therefore, ZOE is typically mixed on a cooled glass slab to slow the setting reaction (Fig. 21.5). Condensation (humidity) on the cooled pad will accelerate the setting reaction and negate the cooling effect. The powder-to-liquid ratio for the mix is dictated by the use of the cement. When mixing a ZOE base material, sufficient powder must be incorporated to produce a stiff, putty-like consistency (Box 21.2).

Zinc phosphate (ZP) cements are the oldest and least expensive cements. They have high compressive strength and good thermal insulation properties and historically have been used as a restoration intermediate layer between gutta percha (GP) and the final composite restoration. Due to the acidic nature of the material, ZP is not recommended as a base in cases with direct or near pulp exposure.⁶

Glass ionomer (GI) cement is currently the most popular base material. The properties of GIs are discussed below, under Direct placement restorative materials.

Direct placement restorative materials

The ideal restorative material would allow for conservative cavity preparation, be easy to apply, bond to the substrate (dental tissues), have the similar strength, thermal, and wear characteristic to the tooth, and be the same color as the tooth. No material has all of these ideal characteristics. Therefore, a material, or combination of materials, must be selected based on its specific advantages in a specific situation. Three basic groups of restorative materials are used in veterinary dentistry: amalgam, glass ionomers, and resin composites. These materials have also been combined to produce materials (e.g., resin modified glass ionomers) in an attempt to gain the advantages and minimize the disadvantages of the base materials.

Dental amalgam is the alloy of mercury mixed with other metals (usually silver, tin, and copper). This material has

^aCaulk IRM, DENTSPLY International Inc., York, PA, USA.

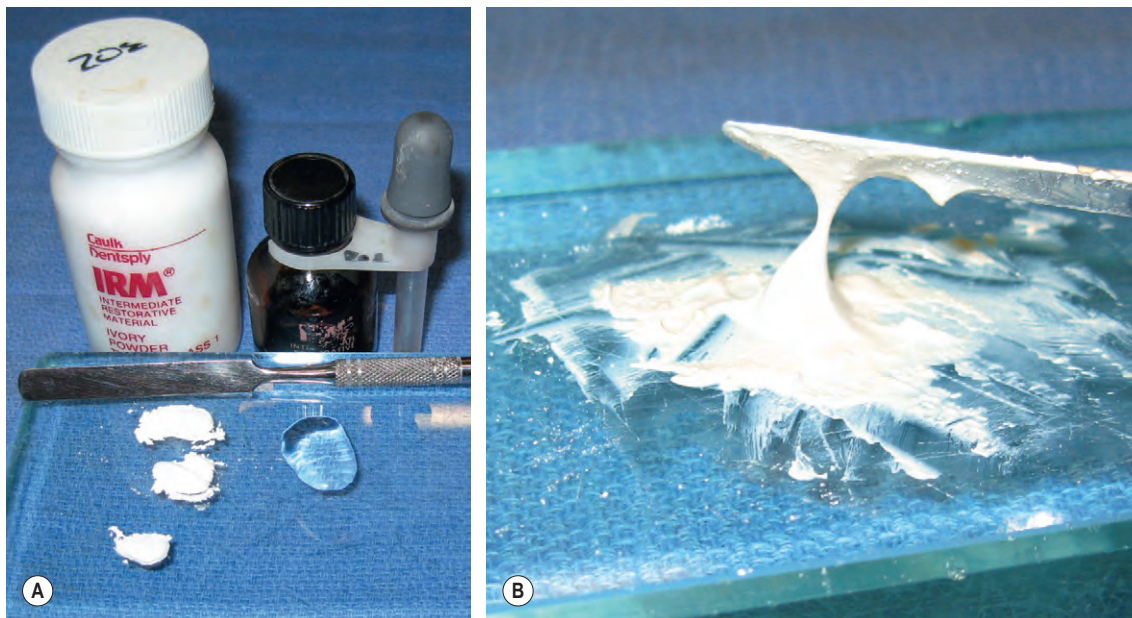


Fig. 21.5 Mixing dental cement. (A) The zinc oxide powder and the eugenol liquid are placed on a glass slab for mixing. (B) Properly mixed cement has a uniform creamy consistency that can be pulled approximately 1 cm.

Box 21.2 Preparation of dental cement (zinc oxide-eugenol)

- A small amount of powder is placed on a mixing slab or pad. A few drops of liquid are placed onto the slab beside the powder.
- Approximately $\frac{1}{4}$ of the powder is pulled into the liquid and mixed with a spatula to a creamy consistency.
- Another $\frac{1}{4}$ of the powder is incorporated into the mixture and spatulated.
- The remainder of the powder is pulled into the mixture and spatulated.
- The final consistency of the mixture is dictated by the cement's intended use; however, for most applications, the cement is properly mixed when a one-cm string can be pulled between the mixing pad and the spatula.

been the primary direct restorative material in human dentistry for over a century due to its ease of use, low technique sensitivity, ability to maintain cavity form, and wear resistance. Amalgam is considered the gold standard for load-bearing (occlusal) restorations. This material is losing favor among human dentists and has seen minimal veterinary use due to its material disadvantages and also due to the popularity of modern composite materials. The toxicity of mercury requires special handling. Current evidence does not support the popular concerns about systemic toxicity secondary to dental fillings.⁷ Amalgam corrodes over time, and the metallic color is esthetically displeasing. Amalgam *does not bond* to dental tissues and is retained by macromechanical forces, which necessitates additional cavity preparation steps, such as dentinal undercutting, and makes the restoration susceptible to marginal leakage. Finally, the applicability of amalgam in equine teeth is uncertain due to the enamel/cementum configuration on the occlusal surface of equine hypsodontic teeth.⁸

Dental composites are the most commonly used restorative materials in veterinary dentistry. They are easy to apply, provide acceptable strength and wear resistance, and are esthetically pleasing. Modern composite bonding systems to dentin and enamel require limited cavity preparation and greatly reduce marginal leakage. A composite is a solid material formed from multiphased materials that have been combined to produce properties superior to the individual constituents.⁹ Dental composites contain three major components:

1. Matrix: an acrylic resin consisting of monomers polymerized using free radical initiators to form a solid material
2. Fillers: glass, ceramic, or composite particles that reinforce the resin matrix
3. Coupling agents: an organosilane, coats the filler particles, and covalently bonds to the matrix resin.

Other components in dental composites include tooth colored pigments, the polymerization activator-initiator system, and polymerization inhibitors to control the working time.

All commercial dental composites use free radical initiators to start an addition polymerization reaction. These free radicals are activated either chemically, by an external energy source (e.g., a curing light), or by a combination of the two mechanisms.

Light-activated resins (light-cured) are packaged as a single paste in a light-proof container (i.e., syringe or compule). Light in the visible blue range (450–475 nm) excites a photosensitizer, commonly camphorquinone, which reacts to the amine activator to produce free radicals. The advantages of light-activated resins are an unlimited working time for material placement and a short, 'on demand' set time (usually 30–60 seconds). The depth of cure for light-activated resins is accepted to be approximately 2 mm; therefore deep restorations must be applied using a layering technique

(incremental buildup).^{10,11} In addition to ensuring maximum polymerization conversion, the layering technique minimizes resin shrinkage. The curing light should be held within 1 mm of the restoration to optimize light exposure, or the activation time should be extended. Light-activated resins are initiated by visible light and must be protected from room lights, especially surgical lamps. The minimum energy requirement to initiate the photosensitizer is 300 mW/cm². Curing lamps should be tested periodically with a radiometer to ensure adequate emission. Because of the intensity of the light produced by curing lamps, operators should never look at the blue light and should use an orange protective shield or glasses to protect against retinal damage.

Chemically activated resins (self-cured, auto-cured) are packaged as two paste systems. One paste contains a benzyl peroxide initiator, and the other paste contains an aromatic tertiary amine activator. Upon mixing, polymerization begins, and the composite sets into a solid state within 3–5 minutes. Heat increases both the rate and degree of polymerization. Chemically activated resins are usually used for large, bulk fill restorations or restorations with limited light access.

Dual-cure resins are chemically activated resins in which a light activation system has been added to each paste and are indicated in restorations where light cannot penetrate the entire depth of the restoration. Light activation attains the initial set of the restoration, and the chemical activator completes the polymerization. Whether the composite is light or chemically activated, the polymerization reaction continues for at least 24 hours before the resin is completely cured. An unfilled resin coating is applied to protect the restoration from air and oral fluids during this curing period. This technique is referred to as 'rebonding.'

Historically, the most significant problem with dental composites has been shrinkage of the matrix material during polymerization. This shrinkage creates a gap between the restoration and the cavity wall referred to as *marginal leakage*. In order to reduce the volumetric change within the matrix, high molecular weight monomers, which covalently bond to other polymer chains, are used. Most contemporary dental resins use a combination of bisphenol A epoxy and glycidyl-methacrylate (Bis-GMA) and triethylene glycol dimethacrylate (TEGDMA) monomers to limit matrix shrinkage. These monomers also cross-link between polymerization chains to produce a composite with increased physical and mechanical properties.¹² Additionally, high levels of filler particles reduce the amount of matrix in the composite, which also limits the polymerization volumetric change. Increased filler loading increases the restoration hardness, fracture strength, and wear resistance and reduces thermal expansion and contraction. While the combination of high levels of Bis-GMA and filler loading minimizes marginal leakage and improves the mechanical properties of the restoration, it also results in a viscous material with poor handling characteristics. Therefore, numerous composite materials are manufactured in an attempt to maximize the physical, mechanical, and handling properties required for different restorative applications.

Dental composites are commonly classified by the filler particle size:

- **Conventional (traditional, macrofilled) composites.** These stress-bearing composites have the largest

particles (8–12 µm) and are rarely used because newer composites outperform them. Although they are strong, their surface is notably rough, discolors, and wears unevenly.

- **Microfilled composites.** These composites were designed for superior polishability and contain filler particles in the 0.04–0.4 µm range. They are indicated for low-stress, esthetic restorations and are not popular in veterinary medicine because they lack strength and wear resistance.
- **Hybrid composites.** These composites have a high filler content and contain various sizes of particles ranging from 0.2–3 µm. They are currently the preferred restoration material in human and veterinary dentistry because of their wide range of uses, their superior clinical properties, wear resistance, and acceptable polishability. They are used in stress-bearing and esthetic restorations. The following hybrid composites are further grouped into subcategories.
- **Microhybrid composites.** This subcategory of hybrid composites combines filler particles of submicron (0.04 µm) and small (0.1–1.0 µm) sizes. They were developed to offer a composite for high stress as well as esthetic restorations. In general, they have superior strength, but polishability is not better than traditional hybrids. This is the most popular category of composites because of their versatility.
- **Flowable composites.** This subcategory of hybrid composites consists of low viscosity (syringeable) composites with reduced filler content that flow and adapt intimately to the cavity walls. They are only recommended in low stress restorations and restorations with poor accessibility because they lack strength and wear resistance.
- **Packable composites.** This subcategory of hybrid composites is highly viscous and was designed to be placed similarly to amalgam. They are strong, wear-resistant, and polishable. Packable composites have no superior properties to other hybrid composites and adaptation to the cavity walls is very technique sensitive.
- **Nanofilled composites.** Recent advances in sol-gel technology have made submicron-sized particle production possible. The nano-particle size (0.005–0.01 µm) allows for increased filler loading, which improves strength and wear resistance, as well as minimizing shrinkage.
- **Nanohybrid composites.** These composites combine nano particles and conventional fillers to produce a microhybrid composite with the strength and wear resistance of a traditional composite and the polishability of a microfilled composite.
- **Core (buildup) composites.** These high-strength composites were designed for placement under prosthodontic crown restorations where significant tooth structure has been lost. Filler particle sizes vary from micro to macro, and polishability is poor. Anecdotal success in restorations of incisor fractures and extensive decay has been reported.
- **Compomers (polyacid modified resin composites).** These composites have a polyacid modified resin matrix with composite and glass ionomer fillers. They release low

levels of fluoride and are indicated for low-stress restorations in patients at risk for caries. Since they exhibit poor physical properties and wear resistance and release lower levels of fluoride than traditional or resin modified glass ionomers, compomers have seen little clinical use.

No clinical trials have been performed to study the use of any restorative material in equine hypsodontic teeth. However, clinical success using microhybrid composites to restore infundibular cavities was first reported in 2001.¹³ The use of core composite material in large defects has also been reported.¹⁴ The use of flowable composites in equine teeth has become a common practice because of the material's handling characteristics and the adaptability of the material to the cavity; however, this application must be questioned due to the poor mechanical properties of the material. Nanocomposites have the potential to make a significant improvement over the available composite materials in both human and veterinary patients but have seen limited clinical use.

Dentin-enamel adhesives (bonding agents)

Except for compomers, composite restorative materials are hydrophobic and will *not* bond to hydrophilic dental tissues. Therefore, composite restorations require an adhesive application to which the composite resin can copolymerize. Adhesion is the bonding or attachment of dissimilar materials so that the materials resist separation and transmit mechanical forces across the bond. Regardless of the substrates being joined, adhesion promotion follows a prescribed generic methodology: 1) substrate preparation; 2) surface priming; and 3) placement of application-specific overlayers that react with the primer. With the exception of glass ionomers, which chemically bond to dental tissues, all modern adhesive systems follow this generic adhesive methodology.¹⁵

Substrate preparation dissolves the barrier layers that inhibit primer interaction with the substrate. In heterogeneous substrates, such as dentin and enamel, selective removal of substrate components also enables more efficient surface reactions, alters surface conformation, and changes the surface energy. Acid etching (also called conditioning) is the required surface preparation technique for bonding of restorative materials to dental tissues. Acid etching enamel removes the smear layer created by instrumentation, dissolves apatite crystals to create a microporous surface, and lowers the surface energy, which facilitates spreading (wetting) of the primer. In addition to the surface preparation effects noted for enamel, acid etching dentin increases permeability by widening the dentinal tubules and exposes acid insoluble type 1 collagen fibers, which represent approximately 90% of the organic phase of dentin (Box 21.3).

After a substrate is prepared, a *primer* is applied to the substrate. The primer consists of molecules with chemically functional terminal groups that react to the adherends. Dental primer monomers have an adhesive hydrophilic group, which reacts with the enamel or dentin, and a hydrophobic polymerizable group that cross-links with the restorative resin. The primer is carried in acetone, ethanol, or water. The function of the primer on enamel is to completely wet the surface of the enamel and to penetrate the microporosities created by the etchant. Polymerization of the bonding

Box 21.3 Acid-etch technique

35% phosphoric acid is the 'gold standard' etchant, although other acids (e.g., polyacrylic acid) and varying acid concentrations are available. Etchants are available in liquid and gel forms, with the gel being the most popular because it is easier to dispense and because it retains its placement during vertical applications.

The etching procedure includes the following steps:

1. The preparation is isolated to prevent contamination from blood or oral fluids.
2. The tooth and cavity preparation are cleaned with non-fluoride flour pumice to remove the organic pellicle, plaque, food, and other oral fluids. The pumice is mixed with water into a thick paste and applied with a prophy cup on a low-speed handpiece. Fluoride polishing paste is contraindicated because it interferes with the etching reaction.
3. The cleaned area is rinsed and gently air dried.
4. The etchant is applied to the preparation for appropriate contact time, and then thoroughly rinsed off with water. The standard contact time for dentin is 10–15 seconds and for enamel is 30–40 seconds. The etching time for coronal cementum has not been established; however, the author (SSG) allows 20–30 seconds contact time for cementum. Over-etching should be avoided since a contact time over 120 seconds leaves insoluble calcium precipitates on the surface of enamel.
5. The etched surface is dried according to the adhesive material instructions. Most enamel bonding systems require a dry etch surface, and properly conditioned enamel has a chalky-white or frosty appearance. If this appearance is not achieved, the surface should be re-etched. Most dentin bonding systems require a moist surface with a glistening appearance. Drying the dentin desiccates and collapses the collagen fibrils, which prevents proper bonding.
6. The conditioned tooth is protected from contamination until the restoration material is applied. In the sedated horse, this often necessitates that an assistant cover the prepared tooth with sterile gauze while the operator prepares the restorative material.

agent interlocks the primer into the microporosities and forms a micromechanical bond. In dentin, the primer infiltrates the dentinal tubules (micromechanical bonding) and entangles the collagen fibers exposed during etching, which upon polymerization, forms the hybrid layer. Hybrid layer formation is the primary bonding mechanism in dentin bonding systems (Fig. 21.6). Finally, interfacial resin overlayers, with extensive crosslinking capabilities, are applied which copolymerize with both the primer and composite resin.

Bonding agents have traditionally been classified based on generational sequencing, chronologically based on market introduction (Box 21.4). Advances in this classification system are generally indicative of a reduction in the number of application steps in the bonding procedure and are not indicative of improved bonding performance. Since the generational classification system has no correlation to improved bonding strength, Stangel et al proposed a contemporary bonding system classification based on whether the acid conditioner (etchant) is rinsed off the dental tissue or left in situ.¹⁵

The 'etch and rinse' (ER) category is divided into two- or three-step systems in which the first application step is *always* the etching step (Step 1). In the Two-Step ER system (One Bottle System), the primer and adhesive resin overlayer is

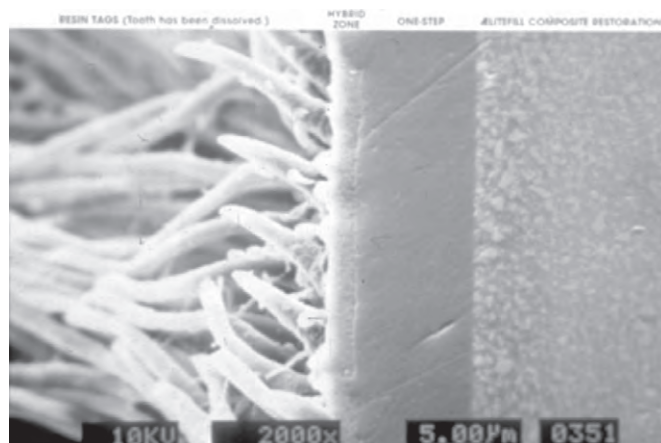


Fig. 21.6 The bonded composite resin. Resin flags are formed from the flow of the dentin bonding agent into the dentinal tubules. A hybrid layer is formed by the interaction of the resin and the collagen fibers of the decalcified dentin. The composite resin is bonded to this hybrid layer interface. (From Gladwin M and Bagby M 2000. Clinical aspects of dental materials. Lippincott, Williams and Wilkins.)

Box 21.4 Generational classification of bonding agents

Since dentists commonly refer to bonding agents with respect to the generational classification system, the following outline is included:

1st generation:

- Introduced in the 1950s
- Poor clinical success.

2nd generation:

- Introduced in the late 1960s and early 1970s
- Poor clinical success.

3rd generation:

- Introduced in the early 1980s
- Application of the dentin conditioner (etchant), primer and adhesive in distinct steps.

4th generation:

- Introduced in the mid-1980s
- The Total-Etch Technique (simultaneous aggressive etching of enamel and dentin with phosphoric acid) and the dentin 'Wet Bonding' process were introduced
- Acceptable bonding strength
- Numerous procedural steps.

5th generation:

- Introduced in the early 1990s
- The 'Etch and Rinse' systems
- Developed to reduce the number of procedural steps
- Improved clinically consistent results
- These systems are the most commonly used.

6th generation:

- Introduced in the early 2000s
- 'No Rinse' system
- Single-Step Bonding
- Low bonding strength to enamel and poor clinical trials.

applied in a single application (Step 2). In the Three-Step ER system, the primer and adhesive resin overlayer is applied separately (Steps 2 and 3). Within the 'etch and rinse' category of bonding agents, the Two-Step (One Bottle) system is the most popular. While both the Two- and Three-Step ER systems produce acceptable bonding strengths to both enamel and dentin, the Three-Step ER system has superior bonding to dentin (Fig. 21.7).

The 'no rinse' (NR) (self-etch, self-priming) category is divided into one- or two-step systems. In the One-Step NR system, the conditioner, primer, and adhesive resin overlayer is applied together from a single bottle. In the Two-Step NR system, the combined conditioner and primer components (first bottle) are applied, followed by the application of the adhesive resin overlayer (second bottle). The NR bonding systems have failed to produce clinically acceptable bonding strength when compared to the ER systems due to poor removal of the dentin smear layer. If a 'no rinse' bonding agent is used for bonding to enamel, a preparatory 'etch and rinse' step has been recommended.¹⁶ However, this additional step defeats the entire purpose for the 'no rinse' system.

In 2005, a review of 85 performance trials evaluated the clinical effectiveness of six dental adhesives systems (2-Step ER, 3-Step ER, 1-Step NR, 2-Step NR, and glass ionomers (GI) with and without conditioning).¹⁷ The study found a high degree of variability within each group but made several general conclusions about contemporary bonding systems (Box 21.5).

Glass ionomer cements

Glass ionomer (GI) cements are a group of materials based on the reaction of silicate glass powder and polyacrylic acid. GIs *chemically bond* to dentin and enamel by crystal formation when the GI's carboxyl group chelates with the calcium in the apatite in dentin and enamel. Although this bond is not as strong as that formed by resin-based dentin bonding systems, the clinical retention of GIs in low-stress applications is excellent.¹⁸ Additional bond strength can be attained by conditioning the walls of the cavity with 34–37% phosphoric acid or 10–20% polyacrylic acid to remove the smear layer to allow for micromechanical bonding to the dentin and enamel.¹⁹ The chemical bonding of GIs allows for conservative cavity preparation and placement into moist fields, and GIs have shown clinical success when placed in incompletely debrided cavities (atraumatic restorative treatment).²⁰ GIs have a modulus of elasticity similar to dentin and a coefficient of thermal expansion comparable to tooth structure, which minimizes marginal microleakage and thermal conduction. The unique property of GIs is the release of high levels of fluoride ions over the life of the restoration, which is known to strengthen enamel, decrease dentin sensitivity, and provide an antibacterial and cariostatic effect to the surrounding tissues. Finally, GIs are relatively biocompatible with pulp.

GIs also have several disadvantages that must be considered during treatment planning. Their use is limited to low-stress applications because low compression and flexural strength make them brittle and susceptible to fracture and cause poor wear resistance. GIs are technique sensitive during preparation and placement and must be mixed and applied exactly according to the manufacturer's



Fig. 21.7 Placement of an 'Etch and Rinse' (5th generation) bonding agent (BA) after incisor odontoplasty. (A) The occlusal surface is acid etched, and then rinsed and left damp. (B) The BA is applied and brushed onto the surface. (C) The BA is light cured, and then a second application is made.

Box 21.5 Conclusions about contemporary bonding systems based on a review of clinical trials¹⁷

1. The 3-Step ER systems out-performed the 2-Step ER systems due to phase separation and incomplete infiltration into the demineralized zone with the latter system
2. Several NR systems required selective enamel etching to be effective; therefore, they are not a true NR system
3. 2-Step NR systems showed clinically reliable performance in non-load-bearing restorations
4. 1-Step NR systems had ineffective clinical performance and had the highest failure rate of all systems
5. Resin Modified GIs performed comparably to 3-Step ER systems and better than conventional GIs
6. Although anecdotal reports may support the use of these bonding systems in load-bearing restorations, no systematic data exist to recommend this application.

Box 21.6 The basic technique for a composite restoration

1. The cavity or endodontic access is prepared (cavity preparation; Fig. 21.4).
2. In deep cavity preparations and endodontic access restorations, a liner and/or base material (e.g., calcium hydroxide, glass ionomer, and Reinforced Zinc Oxide-Eugenol Cement) may be applied.
3. The walls of the cavity are conditioned (Acid Etch Technique; Fig. 21.8).
4. A bonding agent is applied to all etched surfaces with a disposable brush and light cured. Most manufactures suggest two applications of the bonding agent (Fig. 21.8).
5. The resin composite is applied into the cavity and shaped with a plastic instrument. Chemical cure composites are typically applied in bulk, while light-curing and dual-curing composites are applied and cured in 2 mm increments to allow for proper curing of composite and to minimize the shrinkage of the restoration (incremental buildup). Low viscosity materials in vertical restorations can be held in place with a mylar strip (Fig. 21.9).
6. The cavity is filled to the coronal margin, or slightly overfilled.
7. The restoration surface is contoured with a diamond finishing burr on a high-speed water-cooled handpiece and then finished with finishing stones and discs on a low-speed hand piece (Fig. 21.10).
8. The restoration surface and marginal tissues are sealed by re-etching and applying two coats of bonding agent (Rebonding; Fig. 21.11).

Box 21.7 Classifications of glass ionomer cements

- Type I:** Luting cements used to bond crowns and orthodontic appliances
- Type II:** Restorative materials
- Type III:** Bases and liners used under composite materials
- Type IV:** Admixes, light-curing bases, and liners.

specifications for handling and working time. GIs should be manipulated as little as possible during the initial setting period, usually four to five minutes. GIs are often provided as a liquid and a powder which are mixed and applied as a tacky liquid, which lumps upon placement into a cavity. The consistency of the prepared material often necessitates the use of a mylar strip to hold the material in place during initial setting when the cavity is located on a vertical wall (i.e., a peripheral cavity on an incisor) and makes application into an occlusal maxillary cavity difficult (i.e., incisor root canal therapy restoration) or impossible (i.e., cheek tooth infundibulum). To improve handling sensitivity, some GIs are packaged in syringes that dispense a premeasured volume of two gels, which are then mixed or in capsules which are mixed with an amalgamator and dispensed directly into the cavity. *Resin modified glass ionomers* have also been developed to allow for instant light-cured initial setting of the material, as well as improving strength. The final disadvantage of GIs is their extended curing time (months), which necessitates protection of the restoration surface from desiccation. Protection during curing is commonly provided by the placement of an unfilled resin on the restoration surface and peripheral dental tissues (enamel and cementum in the horse; rebonding technique).

Because of the unique chemical bonding and fluoride releasing properties, GIs are formulated for many dental applications (Box 21.6, 21.7 and 21.8). Although GIs are very popular in human dentistry in luting applications (Fig. 21.12) and in restorative applications in patients with high risk for caries (Fig. 21.13), in veterinary medicine GIs are primarily used as liners under composite restorations to protect the pulp and to augment marginal sealing (Fig. 21.14). This application is commonly referred to as the 'sandwich technique'.²¹ Before using a GI, practitioners must



Fig. 21.8 Conditioning and bonding of the cavity. (A) The cavity preparation is conditioned with 37% phosphoric acid, and then rinsed and left damp. (B) Two layers of an 'Etch and Rinse' bonding agent are applied to the cavity preparation. Note the shiny appearance of the bonded dentin.

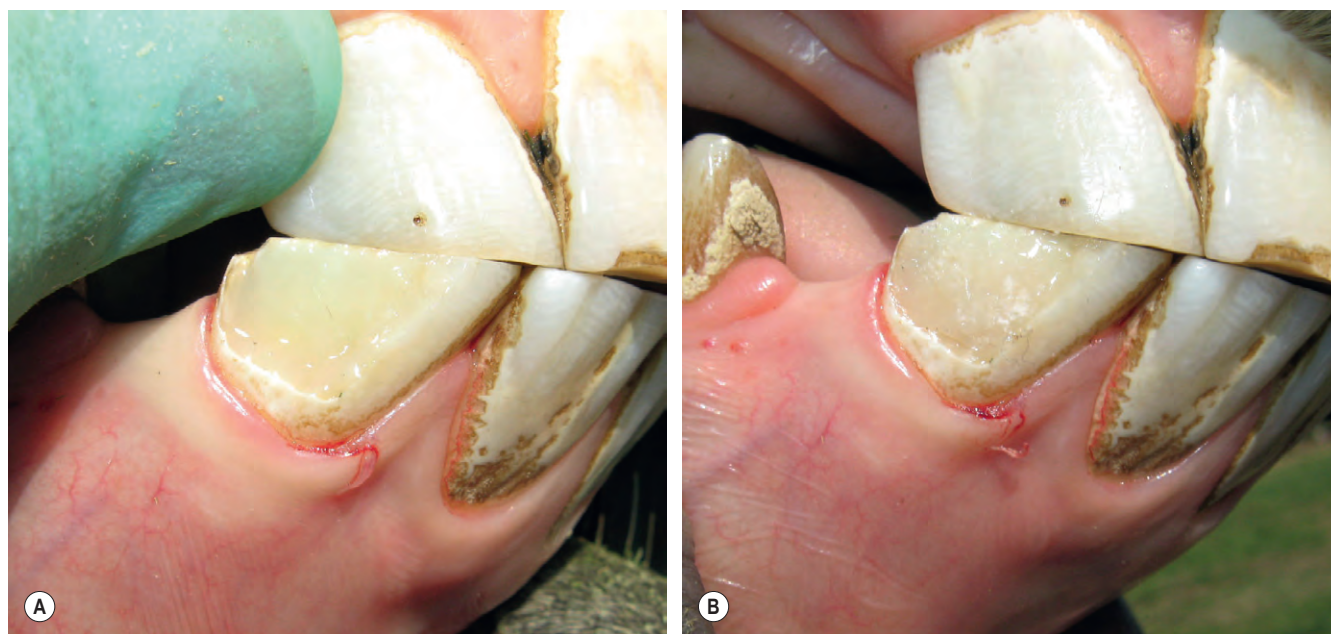


Fig. 21.9 Incremental filling of the cavity with a light-cured resin composite. (A) The first layers are placed and adapted to the walls of the cavity. (B) The remainder of the cavity is filled in 2-mm increments.

consider that the hypsodontic eruption of equine teeth might eventually put a restoration into an occlusal, load-bearing location, for which a GI is inappropriate.

Endodontic materials

Endodontic irrigants

Endodontic therapy involves the preparation, sterilization, and obturation of a diseased pulp canal (see Ch. 22).

Irrigation during root canal therapy is required to remove the smear layer of dentin shavings, cellular debris, and pulp remnants created during instrumentation and to disinfect the pulp canal. The chemical debridement provided by endodontic irrigants during equine root canal therapy is *critical* since the shape of equine pulp canals rarely allows for complete instrumentation. While the type and the concentration of endodontic irrigants are continuously debated, a SEM study concluded that the volume of the irrigant was the most important factor in removing debris from the canal.²²



Fig. 21.10 Contouring and finishing the restoration. Once the cavity is completely filled, the restoration is contoured to approximate the tooth margins, and then finished to a smooth appearance. Note the dull appearance of the restoration.



Fig. 21.11 Rebonding the restoration. The finished restoration and marginal tissues are re-etched, and two coats of a bonding agent are applied. Note the shiny appearance of the rebonded tooth and restoration.

The effectiveness of all endodontic irrigants is limited by their ability to penetrate to the apex of the canal and into the dentin tubules; therefore, all irrigants should be replenished frequently to ensure effective chemical concentrations and removal of debris. Replenishment after each instrument change, or at least every two minutes, is commonly accepted. Ultrasonic activation of endodontic irrigants augments penetration into small pulp canal spaces²³ and, theoretically,

Box 21.8 The basic technique for glass ionomer restoration

1. The tooth and cavity preparation are cleaned with non-fluoride, flour pumice.
2. If the manufacturer recommends, or if increased bonding strength is required, condition the cavity with polyacrylic acid (acid etch technique).
3. Mix, or activate (encapsulated GI), exactly according to the manufacturer's instruction. Remove one level scoop of powder and place it on a mixing pad. Divide the powder into three to four aliquots. Dispense the liquid next to the first aliquot and rapidly mix with a mixing spatula. Continue by drawing each aliquot into the liquid until the material is thoroughly mixed. The typical mixing time is approximately 30 seconds; however, mixing on a chilled surface extends the working time. The prepared material should have a uniform, tacky, glossy liquid consistency (Fig. 21.15).
4. Apply the GI to the restoration with a plastic instrument or a compule syringe. In vertical restorations, a mylar strip is usually required to hold the material in place. The initial setting time for GIs is approximately 4 minutes, during which time the material can be manipulated; however, overworking the material should be avoided.
5. The GI must be protected from contamination and drying during the initial setting period (about 20 minutes) by covering the restoration surface with a varnish or unfilled resin.
6. After the initial set, the restoration surface is contoured with a diamond finishing burr on a high-speed, water-cooled handpiece, and then finished with finishing stones and discs on a low-speed hand piece.
7. The restoration surface and marginal tissues are sealed by re-etching and applying a bonding agent (rebonding).

should improve irrigation of the irregularly-shaped equine pulp canals.²⁴

Liquid irrigants are delivered into the pulp canal using a blunt needle on a syringe to prevent extrusion into the peri-apical tissue. Needles with a closed tip and a side port should be used when irrigating with caustic irrigants (see sodium hypochlorite). Irrigants are removed by suction, with a paper point, or by flushing with sterile saline solution. Compressed air should not be used to evacuate irrigants from the root canal since air may be extruded through the apex. Fatalities secondary to air embolism have been reported in a human²⁵ and in dogs.²⁶

The most commonly used irrigant is sodium hypochlorite (NaOCl). It has broad-spectrum antimicrobial efficacy and is a proteolytic solvent that dissolves the organic portion of the smear layer and the predentin layer of the dentin. Free Cl^- ions are responsible for NaOCl's antimicrobial effects. Proteolytic reactions deplete free Cl^- ions; therefore, NaOCl must be replenished frequently to maintain chemical efficacy. Concentrations from 1 to 5.25% (household bleach) have been shown to be clinically effective.²⁷ At room temperature, a total contact time of 20–30 minutes is required to completely dissolve the pulp.²⁸ However, heating increases both the tissue solvent and antimicrobial effects.^{29,30} The effervescence created by mixing sodium hypochlorite and hydrogen peroxide was once a popular flushing technique but this method has been shown to be ineffective.³¹ During conventional root canal therapy (coronal access), slow irrigation with light pressure through a non-binding or side-

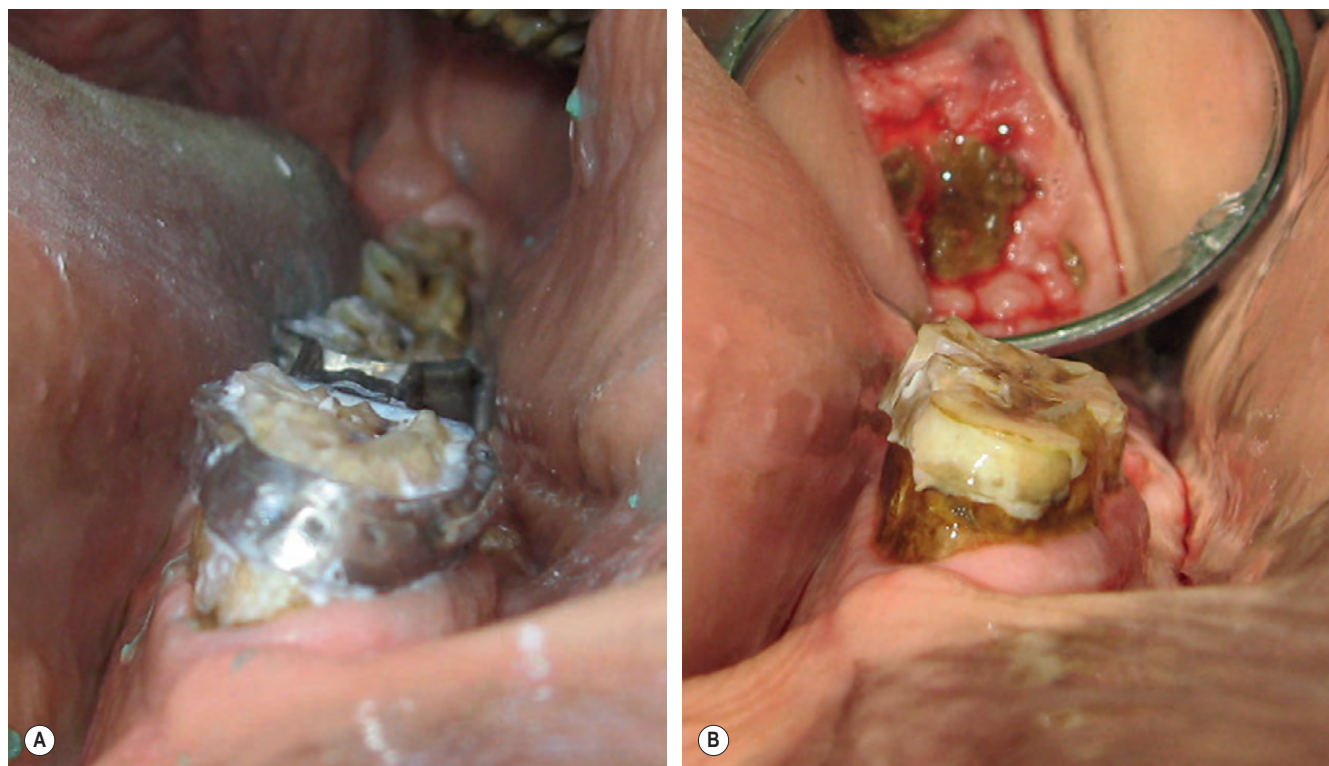


Fig. 21.12 Application of Type I glass ionomer cement. (A) A resin modified glass ionomer was used to cement an orthodontic appliance to the cheek teeth of a young horse. (B) After appliance failure, the glass ionomer cement remains bonded to the cheek tooth peripheral cementum. (Bonding to cementum has not been scientifically evaluated.)

port endodontic needle is advisable since injection of NaOCl through the apical foramen into the periradicular tissue is extremely caustic and causes severe pain, periradicular hemorrhage, swelling, and possible abscess. During retrograde procedures, the periapical tissues should be protected and rinsed frequently with saline solution, and the endodontist should consider using a lower concentration of NaOCl. During procedures on maxillary incisors in the sedated horse, gravity evacuates the irrigant from the root canal. For this reason, higher concentrations of irrigant should be considered.

Ethylenediaminetetraacetic acid (EDTA) is a decalcifying agent that is commonly used to dissolve the inorganic component of the smear layer. EDTA also increases the diameter of the dentinal tubules to allow penetration of disinfectants. A 17% solution is the most common endodontic concentration and removes the smear layer in less than one minute of contact time. Another popular formulation of EDTA adds urea peroxidase for its antibacterial properties in propylene glycol base (RC Prep).^b Although the use of gel and paste formulations as a file lubricant is commonly practiced, the solvent efficacy of these preparations is questionable. Since the chemical efficacy of EDTA is self-limiting, it also must be intermittently replenished. For maximum clinical efficacy, EDTA should have a total contact time of at least 15 minutes.³² NaOCl and EDTA are most effective if their use is alternated.³³

Chlorhexidine, 2% solution, (CHX) is used as an endodontic disinfectant because of its antimicrobial properties, and like sodium hypochlorite, heating enhances this property;³⁴ however, CHX has no tissue solvent properties. The use of CHX has had mixed acceptance. Some dentists irrigate with alternating flushes of NaOCl, EDTA, and CHX for increased disinfection, while others support the use of CHX as the final canal rinse before obturation because CHX binds to dental tissues and has persistent antimicrobial effect.³⁵

When using multiple irrigants the root canal is typically rinsed with sterile saline solution between irrigants, and this is especially important when using CHX. CHX is incompatible with NaOCl and decomposes into a potentially carcinogenic precipitate, parachloroaniline,³⁶ and when CHX is mixed with EDTA, a CHX/EDTA salt precipitates.³⁷ The combination of NaOCl and EDTA inactivates the NaOCl, while the EDTA remains active for a few minutes.³⁸

Intracanal medicaments

Since instrumentation and irrigation of non-vital pulps often leaves viable bacteria in the pulp canal, some endodontists perform staged root canal therapy (multiple visits) to ensure disinfection of the canal. Antimicrobial intracanal medicaments are used between treatments. Historically, volatile medicaments (i.e., formocresol and phenol derivatives) were used for their strong antibacterial properties, but these materials have lost popularity due to their potential toxicity.

^bRC Prep, Stone Pharmaceuticals, Philadelphia, PA, USA.

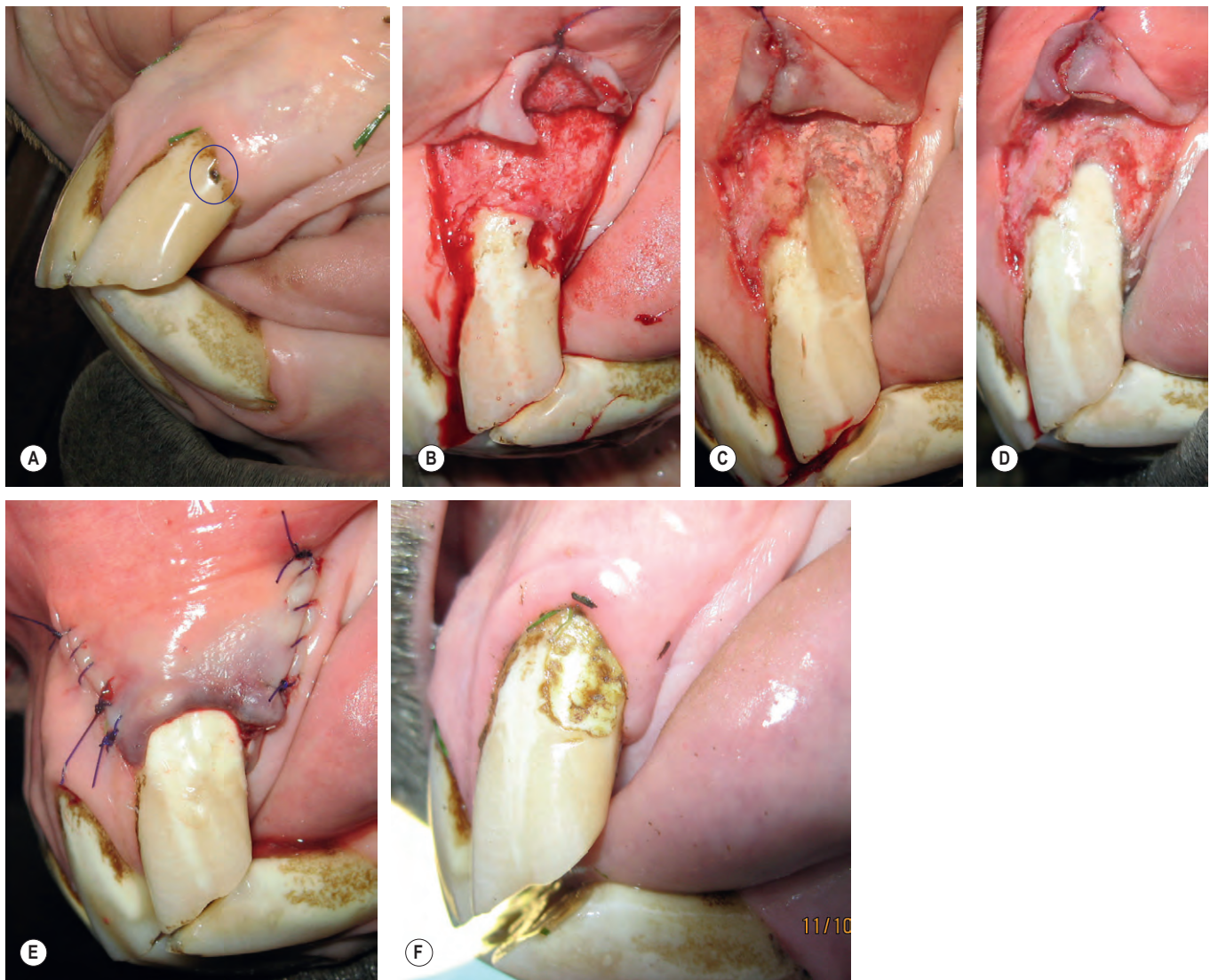


Fig. 21.13 Application of Type II glass ionomer (GI) cement restoration. GI restorations should only be applied after careful and cautious planning because of the hypsodontic eruption of equine teeth. (A) Tooth resorption on the vestibular aspect of the 3rd incisor of a senior horse. (B & C) Cavity preparation of the lesion involved osteoplasty and extensive subgingival debridement of all three dental tissues (Modified Honma Stage 3 lesion). (D & E) A glass ionomer restoration was selected due to the uncertain etiology of the lesion and based on extrapolated applications in human and small animal patients. (F) 1-year follow-up demonstrates retention of the restorative with surface pitting and possible marginal leakage.

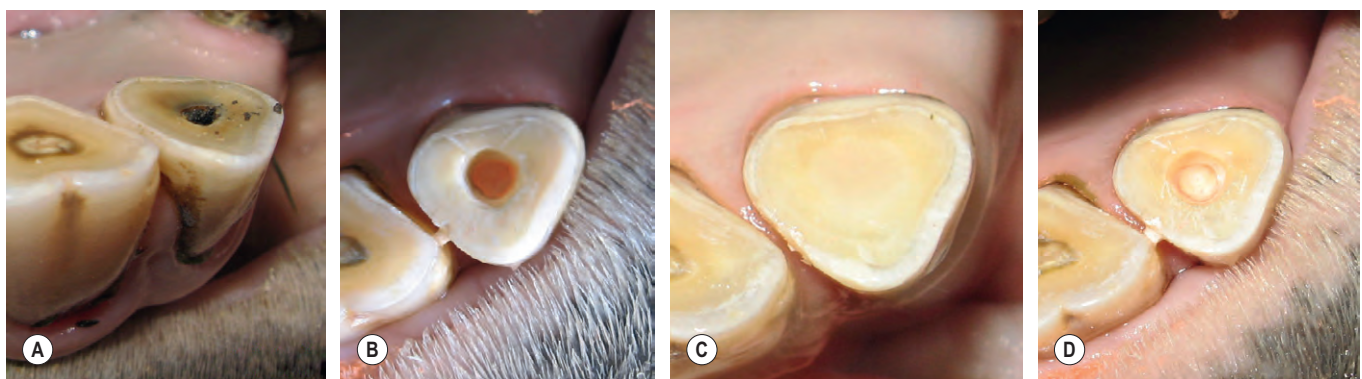


Fig. 21.14 Application of Type III glass ionomer cement (Sandwich Technique). (A) Non-vital pulp exposure of a mandibular 3rd incisor in a teenage horse. (B) Gutta percha (orange) and ZOE obturation of the root canal. (C) Glass ionomer liner application over the gutta percha. (D) The final resin composite restoration of the root canal access.

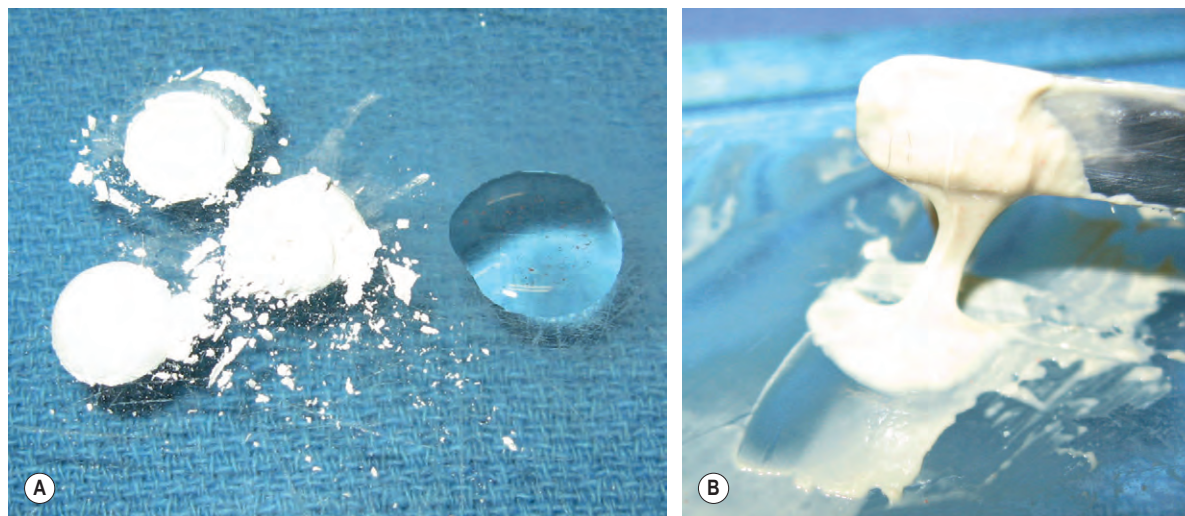


Fig. 21.15 Mixing a glass ionomer (GI). (A) The GI powder and liquid are placed upon a glass mixing block. (B) The powder and liquid are rapidly mixed into a uniform, tacky, glossy liquid consistency.

Calcium hydroxide (CaOH) has both scientific and popular support in several endodontic applications. CaOH has traditionally been the material of choice for the treatment of exposed pulp tissue (direct pulp capping) and for apexification of non-vital pulp canals in immature teeth (Fig. 21.16) because of its biocompatibility and reparative dentin induction property; however, Mineral Trioxide Aggregate (discussed below) is rapidly replacing CaOH in these traditional applications. Because of its potent bactericidal properties, CaOH is also the material of choice for intracanal medicaments during staged (multiple visits) root canal therapy. In addition to the bactericidal effect of strong alkalinity, CaOH also hydrolyzes the lipid component of the lipopolysaccharides in bacterial cell walls.³⁹ In equine dentistry, CaOH has been routinely used as a stand-alone pulp capping material after iatrogenic pulp exposures during occlusal equilibration. As discussed above (Bases and liners), this application is inappropriate.

Obturation materials

Obturation is the complete filling and hermetic sealing of the prepared and sterilized root canal. Obturation systems typically require the combination of a solid obturation material and a sealer. Endodontic sealers bond to dentin to provide a hermetic seal, but excessive shrinkage during curing can cause seal failure; therefore, the solid obturation material provides a base for the sealer to minimize shrinkage. Solid obturation materials include gutta percha (GP), silver, and synthetic polymers. Compared to GP, silver has poor sealing properties, and corrosion produces cytotoxic salts. Consequently, the use of silver as an obturation material is below the current endodontic standard of care. A polyurethane based obturation material (Resilon)^c is being used in both human and small animal dentistry in resin-based obturation systems. This material is non-toxic, non-mutagenic, and biocompatible, has superior coronal sealing

compared to GP, and may strengthen the root.⁴⁰ However, no clinical successes using resin-based obturation systems in the horse have been reported.

GP is the oldest, least cytotoxic, and most commonly used obturation material. It is also the only solid obturation material with reported use in equine endodontics. Natural rubber and GP are the cis and trans isomers, respectively, of the isoprene monomer, which is extracted from the juices of trees in the sapodilla family. Dental GP typically consists of approximately 20% GP, 75% zinc oxide, metallic sulfates for radio-opacity, and other waxes and resins. GP is supplied in cones of various shapes and lengths, but also in cones tapered to match standardized endodontic files. 60-mm lengths are appropriate for most equine application (Fig. 21.17). Most manufacturers package sterilized cones; however, the most common sterilization technique for GP is soaking the cone in 5.25% sodium hypochlorite (NaOCl) for 1 minute.⁴¹ After NaOCl sterilization, the cone is typically rinsed with sterile saline solution. Some dentists believe NaOCl sterilized GP must be rinsed with ethyl alcohol to remove NaOCl crystals, which interfere with the obturation seal.⁴² GP oxidizes if exposed to air, light, and elevated temperatures; therefore, refrigeration is recommended for prolonged storage. GP is incompressible but can be compacted under pressure, and heating it to a temperature above 147° F (64° C) softens GP to facilitate mechanical packing.⁴³ GP dissolves in organic solvents (e.g., chloroform, halothane, xylene), and a GP cone can be softened with a solvent to facilitate placement into irregularly shaped canals by dipping the apical 2–4 mm of the GP cone into the solvent for 1–6 seconds (chloroform dip technique).⁴⁴ GP alone has no adhesive properties and cannot hermetically seal a canal. Endodontic sealer cements are always used in combination with the solid obturation material.

Endodontic sealers are classified as zinc oxide-eugenol-based, calcium hydroxide-based, glass ionomer cements, and polymers. Calcium hydroxide-based sealers are promoted for their therapeutic effects, but have low adhesion to dentin, low water solubility, and have not passed scientific scrutiny. Glass ionomer endodontic cements have excellent

^cResilon, Resilon Research, LLC.

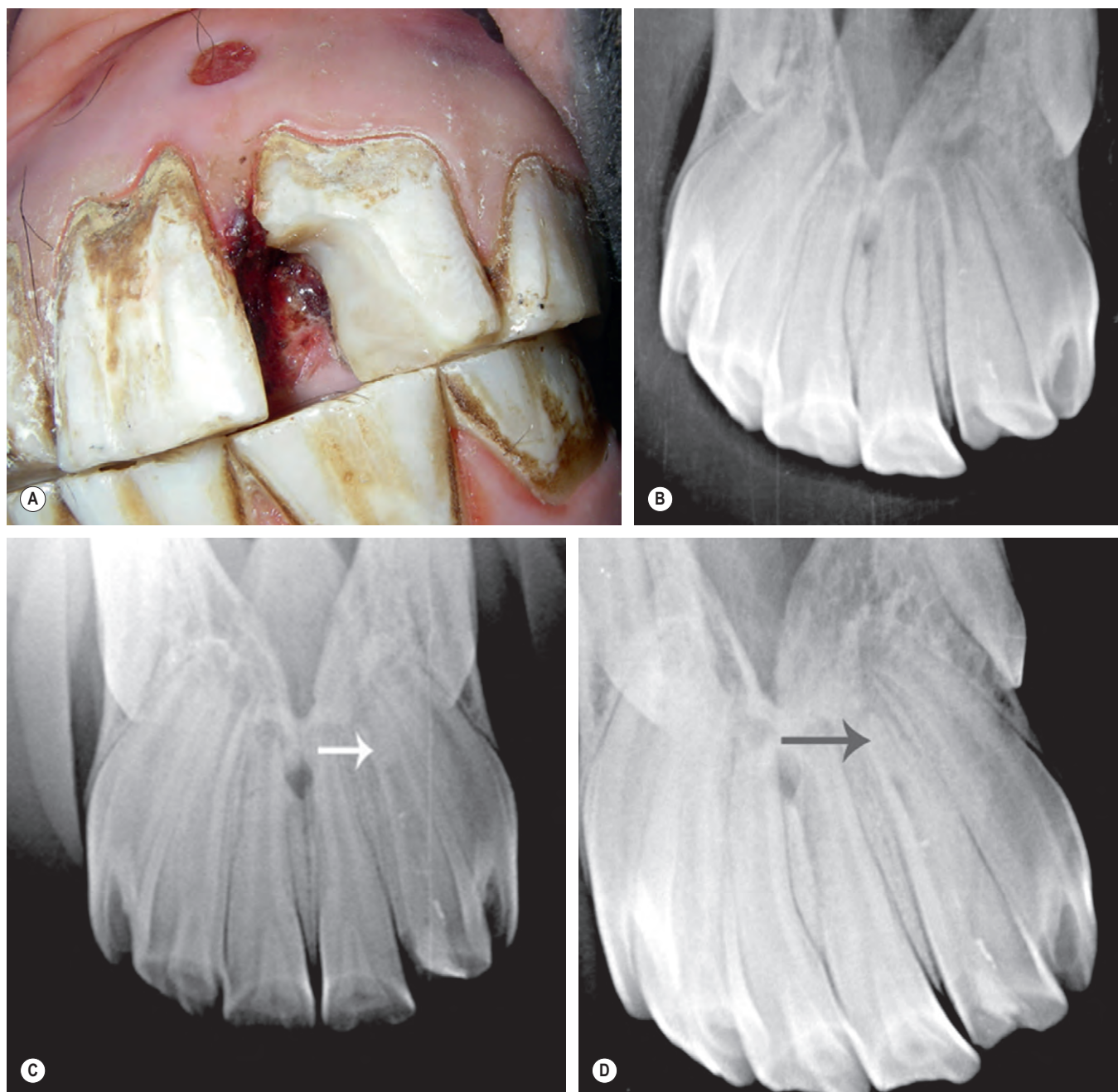


Fig. 21.16 Calcium hydroxide apexification of an equine incisor. (A) Traumatic crown fracture with pulp exposure of an immature 2nd maxillary incisor (202) in a 5-year-old horse. Note the mucosal draining tract. (B) Radiograph demonstrating an apical lucency associated with the open apex of 202. (C) At the five-month follow-up examination, the apex of the 2nd maxillary incisor has mineralized. (D) At the 1-year follow-up examination, the apical periodontium of 202 has re-attached, and root canal therapy was subsequently performed. (Case by permission from Robert M. Baratt DVM.)

biocompatibility and chemical bonding to dentin but are technique sensitive. Polymer sealers are very popular in small animal and human endodontics because of their handling characteristics and dentin bonding, but their use in equine endodontics is unreported. Zinc oxide-eugenol-based sealers are ZOE cements that have been modified with germicides, rosins, resin acids, and other chemicals for endodontic application. They have a long history of success, are the most commonly used sealers, and are the 'gold standard' for scientific comparison. They are mixed as previously described,

and introduced into the pulp canal with a spiral filler on a low-speed handpiece or on an endodontic file. Additionally, each GP cone is usually coated with sealer before placement into the canal.

Thermaplasticized GP obturation systems are widely used in small animal and human endodontics, but no clinical successes in horses have been reported. The small size of the system instrumentation and the complex equine endodontic anatomy limit the application of the thermaplasticized systems in horses. A cold filling obturation system



Fig. 21.17 Gutta percha, which is supplied in a variety of diameters and lengths. 30-mm and 60-mm lengths are commonly used in veterinary medicine, with the latter being more appropriate for equine applications.

(GuttaFlow)^d has been introduced, which might facilitate the filling of irregularly shaped equine pulp canals. The system combines particulate GP with a silicon-based sealer in a prepackaged capsule. After mixing with an amalgamator, the material is injected into the pulp canal, and has a 30 minute curing time before a restoration can be applied. The manufacturer claims that the product expands upon curing. However, this expansion is probably clinically insignificant. Research is needed to validate this product, but initial use in equine incisors and canine teeth has produced inconsistent results. (R Baratt, L Kimberlin, S Galloway, personal communication.)

Endodontic treatment of equine cheek teeth requires apicoectomy and retrograde obturation of the tooth. Historically, amalgam has been the preferred material for apical sealing, but it has lost popularity due to toxicity concerns and the availability of superior materials. Glass ionomer cements, resin composites, and reinforced ZOE cements (Super EBA^e and IRM) have demonstrated better sealing properties than amalgam, while the latter is noted for less technique sensitivity.⁴⁵ Mineral Trioxide Aggregate (MTA)^f is an endodontic material that has recently shown superior performance in numerous endodontic applications, including pulp capping, orthograde apical closure (apexification), perforation repair, and retrograde root-end filling. MTA contains approximately 75 % Portland cement, and upon hydration with water or saline solution, forms a colloid gel that hardens over a 4-hour period. MTA can be placed in a wet environment and is not affected by blood contamination.⁴⁶ The material properties of MTA have withstood extensive scientific testing. Compared to amalgam and reinforced ZOE cements, MTA showed significantly less marginal leakage⁴⁷ and superior marginal adaptation,⁴⁸ and a recent *in vitro* study showed that mixing MTA with chlorhexidine

gluconate did not inhibit its sealing properties.⁴⁹ MTA has a high alkalinity (pH 10.5–12) but is less cytotoxic than calcium hydroxide and induces the formation of a higher quality of and greater amount of reparative dentin than CaOH.^{50,51} Finally, MTA produces minimal periradicular tissue inflammation and is cementogenic.^{52–54} This unique final property establishes the ideal healing environment for the periodontium. In the horse, initial clinical successes have been reported using MTA as a retrograde filling material in a mandibular cheek tooth;⁵⁵ however, this report lacks long-term follow-up.

Periodontal materials

Oral and periodontal irrigants

The treatment of periodontal disease requires the debridement of the periodontal pocket or, in advanced cases, periodontal surgery. Several dental materials are used to augment the effects of periodontal debridement. Pocket irrigation is an important procedure following periodontal pocket debridement to remove the loose debris created by the scaling and root planing procedures. Water, saline solution, and chlorhexidine are commonly used *oral irrigants* in both human and veterinary dentistry. Chlorhexidine has several advantages including: 1) adherence to dental tissues, oral soft tissues, and the pellicle, which prevents bacterial and plaque adherence; 2) a broad antimicrobial spectrum with no reported antimicrobial resistance; and 3) a residual antimicrobial effect.⁵⁶ Chlorhexidine concentrations between 0.02 and 0.12% have been shown in clinical trials to be effective oral irrigants.⁵⁷ A 0.05% solution has also been reported to be effective and non-toxic to tissues as a surgical wound irrigant,⁵⁸ and a concentration of 0.12% was shown to have synergistic antibacterial properties with locally administered tetracycline.⁵⁹ However, if chlorhexidine is used as a surgical irrigant during periodontal surgery (i.e., guided tissue regeneration), it should be thoroughly rinsed from the periodontal pocket at the conclusion of the procedure because chlorhexidine can devitalize periodontal cells and interfere with reattachment to cementum.⁶⁰

Local antibiotic administration (perioceutics) (Box 21.9 and 21.10)

In cases of Stage 2 periodontitis (up to 25% attachment loss),⁶¹ local antibiotic administration (LAA) may be indicated as an *ancillary treatment* after completion of pocket debridement and irrigation. In human dentistry, tetracycline impregnated fibers and doxycycline, minocycline, and metronidazole gels are commercially prepared for LAA. A bio-degradable, polymerized 8.5% doxycycline gel (Doxirobe Gel)^g is labeled for veterinary use in dogs and has been empirically used in other species, including horses (Fig. 21.18). Doxycycline has a broad spectrum of antibiotic activity against several known bacteria associated with periodontal disease, and the degradation of doxycycline gel provides localized, sustained release of antibiotic for approximately 2

^dGuttaFlow, Coltène/Whaledent, Raiffeisenstraße 30, 89129 Langenau, Germany.

^eSuper EBA, Harry J. Bosworth Company, Skokie, IL, USA.

^fProRoot MTA, DENTSPLY Tulsa Dental Specialties, Tulsa, OK, USA.

^gDoxirobe Gel, Pfizer Animal Health, Exton, PA, USA.

Box 21.9 Application of a local antibiotic (perioceutic)

Doxirobe Gel is supplied in a premeasured (1 ml) two-syringe system. For the product to be effective, the periodontal pocket must be debrided and should be dried.

1. The product is mixed according to the labeled instructions using the two-syringe system.
2. A blunt needle is placed onto syringe A for delivery into the periodontal pocket.
3. The pocket is filled to the level of the gingival margin. Many stage 2 periodontal pockets in horses exceed the 1 ml prepackaged volume, and multiple syringes are often required for treatment.
4. Upon contact with crevicular fluid, the gel begins to polymerize. Water drops are typically administered to any exposed gel to accelerate the setting reaction.
5. A plastic instrument can be used to pack any escaping gel back into the periodontal pocket.
6. Covering Doxirobe with an impression material has been described; however, the authors believe that this step is unnecessary since properly placed gel is well retained. Premature dislodging of a local antibiotic administration is probably the result of poor handling technique.

weeks. Additionally, doxycycline binds to dentin, cementum, and bone for prolonged antibiotic release, inhibits the collagenase enzyme (an enzyme that slows the healing of the periodontal tissues), and stimulates fibroblast activity to re-establish the periodontium.^{62,63} The polymer gel also provides a physical barrier for reinfiltration of food and debris into the periodontal pocket, which is an important goal in the treatment of cheek tooth periodontal disease. Although the use of LAAs has become a popular practice in equine dentistry, this ancillary procedure has received no critical evaluation and, in the authors' opinion, has limited indications in the equine patient. Other less expensive materials have shown clinical effectiveness as temporary barrier materials (e.g., impression materials, calcium sulfate, calcium alginate).

Periodontal splinting

Periodontal splinting is a temporary adjunct appliance used in combination with aggressive periodontal therapy to stabilize diseased permanent teeth with mobility or to stabilize mobile teeth during healing after trauma.⁶⁴ Splinting creates a stable platform for osseous regeneration by redistributing the forces applied to the diseased teeth to the adjacent healthy teeth. Before splinting, odontoplasty should be performed on the affected teeth to take them out of occlusion since excessive occlusal loading is a frequent cause of tooth mobility.^{65,66} Splinting materials include acrylics and resin composites used alone or reinforced with interdental wire or fiber mesh (Ribbond).^h Since the accumulation of plaque and debris around the splint promotes periodontal disease, periodontal splinting is best suited to the incisors where the appliance can be cleaned daily (Fig. 21.19).

Box 21.10 The basic technique for fabricating a reinforced composite splint

1. Excessive peripheral cementum is removed from the crowns of the incisors to allow for enamel bonding. This can be accomplished with a whetstone on a low-speed handpiece or a diamond burr on a high-speed handpiece.
2. The teeth are aligned, and a tin foil template is made by molding the foil to the contours of the teeth in the desired application site. The template is then used to cut the reinforcing material to the appropriate length and width. The material should not be handled with bare hands.
3. The teeth are polished with a non-fluoride pumice paste and acid etched.
4. A bonding agent is applied to the teeth and light cured.
5. The mesh is coated with an unfilled resin, and the excess resin is blotted off.
6. A thin layer of filled composite is applied to the bonded surface of the teeth but is not cured.
7. The wetted mesh is applied to the splint site and contoured to the surface of the teeth with a plastic instrument. Excess composite material is removed.
8. The splint over each tooth is light cured. Curing the entire splint requires multiple curing increments.
9. An additional layer of a filled composite is added to the splint, contoured, and cured.
10. The final composite layer of the splint can be shaped or polished to avoid abrasion.

Bone grafting materials

In human and veterinary dentistry, bone grafts are used for guided tissue and bone regeneration (GTR, GBR) in the surgical treatment of advanced periodontal osseous lesions (stage 2–4 periodontitis, >25% bone loss) and of selected periradicular (endodontic) lesions, and for bone augmentation in association with implant surgery. Although the filling of deep post-extraction alveoli with synthetic bone grafting material has been practiced in veterinary dentistry in order to increase the rate of bony healing and to preserve the alveolar ridge, this practice has limited scientific support and is a source of debate amongst veterinary dentists.

Bone grafting materials are classified by their source and by the type of bone growth that they promote. Material can be obtained from the same patient (autogenous bone graft), from a different patient of the same species (allograft), from a patient of a different species (xenograft), or from artificial or manufactured materials (synthetic grafts/alloplastic grafts). The bone growth potential of a graft material is described as osteogenic, osteoinductive, or osteoconductive. Osteogenic materials contain living osteoblasts that produce new bone within the graft itself. Osteoinductive materials possess bone morphogenic proteins (BMP) that induce the differentiation of osteoblasts in the recipient tissue (which does not have to be bone). These osteoblasts then produce new bone. Osteoconductive materials, when placed into bone, provide physically favorable scaffolding for osteoblasts from the recipient tissue to penetrate and form new bone.

Autogenous bone grafts are transferred from one site to another within the same patient. They can consist of

^hPepgen P-15, DENTSPLY Friadent, Postfach 71 01 11, 68221 Mannheim, Germany.

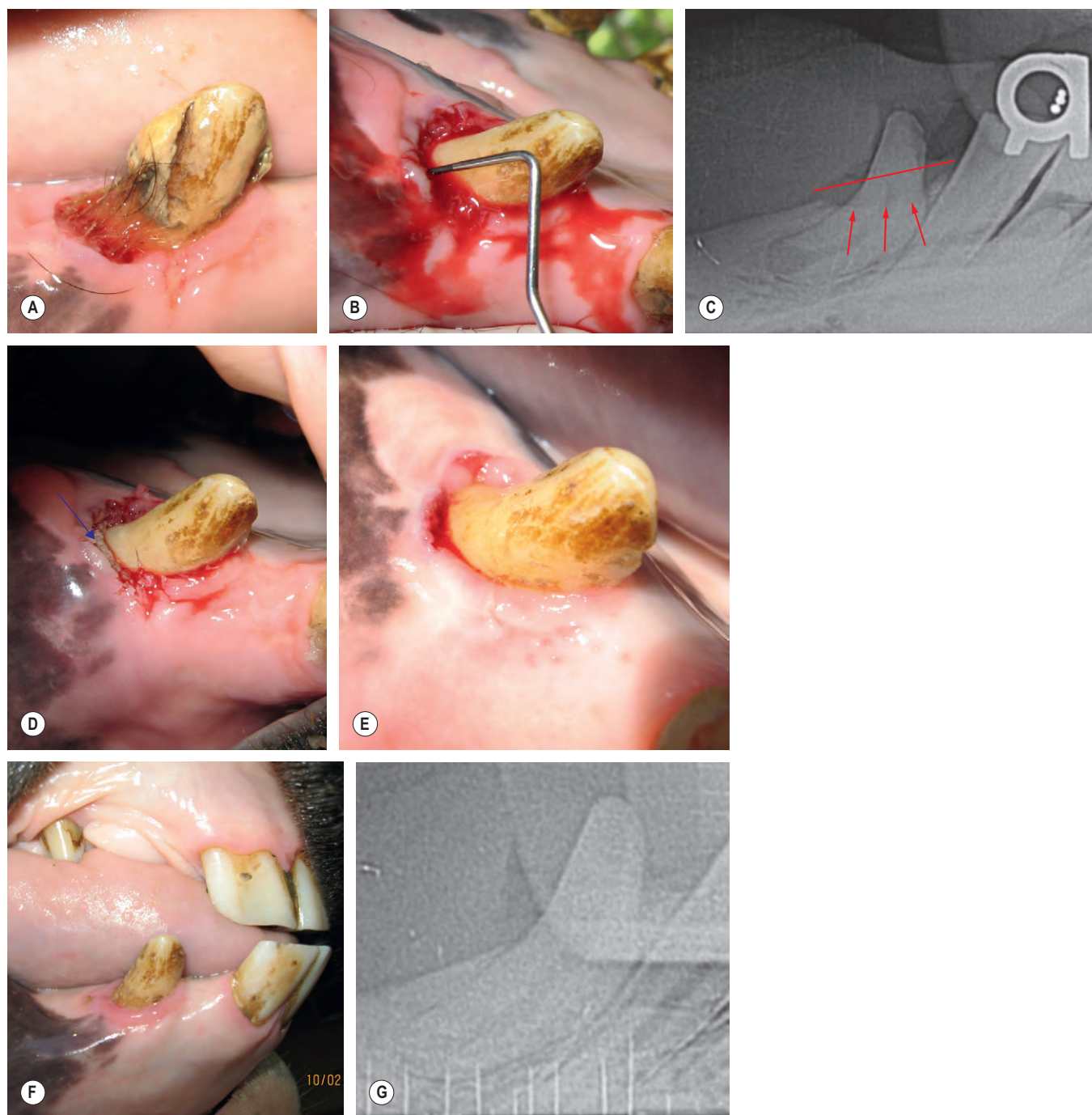


Fig. 21.18 Application of a local antibiotic (periosteal). (A & B) A 12-mm periodontal pocket (PP) on the vestibulodistal aspect of the right mandibular canine tooth (404) of a young gelding. (C) Radiographs reveal horizontal bone loss of the associated alveolar bone (Stage 2 periodontitis). (D) The blue arrow shows the applied Doxirobe Gel in the PP. (Note that the periosteal material fills the entire pocket.) (E) At the 2-week follow-up visit, the PP depth measured 4 mm. (F & G) At the 6-month follow-up visit, probing of the PP produced negligible depth and radiographs revealed alveolar bone regrowth.

cancellous or cortical bone and are the gold standard bone grafting material. These grafts are usually considered osteoinductive but are potentially osteogenic if tissue remains vital. They rapidly revascularize and lack antigenicity. The collection of autogenous bone graft is also associated with the inherent complications and expense of general anesthesia and significant morbidity. Therefore, the other classifications of bone grafting materials have been developed.

Allografts are typically collected from cadavers. Although not routinely used in veterinary medicine, in human medicine, grafts are collected, commercially prepared, and banked for future use. Preparation of the graft degrades the tissue's BMPs; therefore, allografts are osteoconductive. The disadvantages of the materials are antigenicity and the potential for disease transmission.

Xenografts are prepared materials of bovine origin and have had extensive clinical use in human periodontics. Like



Fig. 21.19 Periodontal splinting. Ribbond is used to stabilize a 2nd mandibular incisor after a traumatic injury. (Courtesy of Edward T. Early, DVM.)



Fig. 21.20 Alloplastic (synthetic) bone graft materials. A granular synthetic, bioactive ceramic (Consil) on the left and powdered β -calcium sulfate hemihydrate (plaster of Paris) on the right.

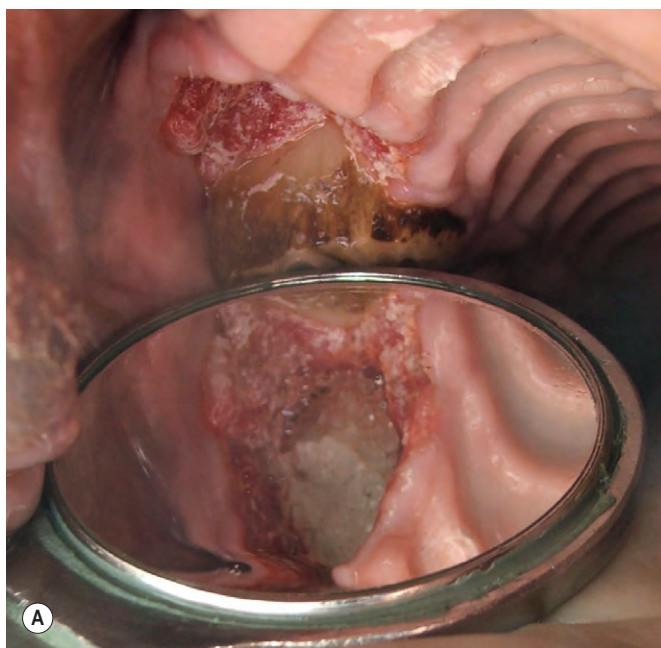


Fig. 21.21 Calcium sulfate used as an alloplastic graft in a post-extraction alveolus. (A) Calcium sulfate placed into the alveolus of the maxillary 1st cheek tooth (106) in a young mare. (B) Gingival healing at 6 weeks postoperatively.

allografts, they are osteoconductive and have the potential for antigenicity and disease transmission.

Several alloplastic (synthetic grafts) materials have been investigated for use in periodontal surgery. All are inert and osteoconductive, with the exception of Pepgen P-15,ⁱ a synthetic amino acid sequence (P-15) mixed with a calcium-phosphate matrix, which has demonstrated osteoinductive potential.⁶⁷ The use of this product has not been reported in an equine patient.

A synthetic, bioactive ceramic derived from calcium salts, phosphates, and silica is labeled for veterinary use 'in infrabony pockets caused by periodontal disease, endodontic-periodontic lesions, traumatic defects, or intraosseous flaws' (Consil Bioglass)^j. The granular material is

coated with hydroxylcarbonate apatite (Fig. 21.20) and, when placed in contact with tissue fluids, incorporates ground proteins and attracts osteoblasts.⁶⁸ This bioactive ceramic is mechanically hemostatic⁶⁹ and has bacteriostatic properties secondary to its high pH.⁷⁰ The material is easy to use and can be prepared by mixing with sterile saline solution, sterile water, or the patient's blood to form a wet sand consistency before placing the material into the host site, or the material can be placed directly into the host site for incorporation with blood.

Due to the large size of the bony defects associated with periodontal disease and dental extraction in the horse, many practitioners use calcium sulfate (plaster of Paris, Dental Stone) as an osteoconductive bone grafting material (Fig. 21.21). Calcium sulfate has been used historically in both human and veterinary medicine in dental and orthopedic applications, and has shown significant regeneration of

ⁱConsil Dental Bioglass, Nutramax Laboratories Inc., Edgewood, MD, USA.

^jRibbond, Ribbond Inc., Seattle, WA, USA.

bone and cementum in the dog.⁷¹ Calcium sulfate is readily available, inexpensive, and biocompatible. The material is supplied as a powder (calcium sulfate hemihydrate), which when rehydrated with water, sets into a solid form (calcium sulfate dehydrate, gypsum). The mixing/working time of the material is usually 2–5 minutes, but varies based on the specific product. The mixed material can be applied into a bony defect through a curved-tip syringe as a viscous liquid during the early phase of the setting reaction or later during the setting reaction by hand or with a dental spatula as putty. Once set, the material is porous enough to allow fluid exchange while dense enough to exclude epithelial and gingival connective tissue migration. The porosity of the material also provides for sustained local release of incorporated antibiotics, especially doxycycline, and for the localized release of calcium ions.⁷² Calcium sulfate resorbs completely over a 2-week period.⁷³ Although calcium sulfate has been used as a bone graft material for over a hundred years, further controlled studies are needed to evaluate its efficacy.

In 2008, the first study reporting the use of bone grafting material in the mouth of a horse was published.⁷⁴ A methylmethacrylate-based, non-resorbable bone substitute was placed into the post-extraction maxillary alveolus in five ponies. Although the material in this study demonstrated excellent biocompatibility and osteoconductivity, it performed inferiorly to the control alveoli with respect to bone mineral density and bone volume at the one-year follow-up evaluation.

Dental impression and cast materials (Box 21.11)

Dental impression materials are used to make accurate molds of the oral hard and soft tissues. The impression is the *negative* reproduction of the tissues. Casting materials are poured into the impression mold to fabricate the dental cast or model, the *positive* reproduction, of the oral tissues. Study models are used for treatment planning and for treatment documentation. Working models are used to fabricate orthodontic appliances and prosthodontic restorations. Two general categories of elastic impression materials are commonly used in veterinary dentistry: alginate hydrocolloids and elastomeric impression materials. Dental casts are molded from epoxy resin or gypsum. Typically, the impression is sent to a dental laboratory that fabricates both the cast and the prescribed appliance.

Elastomeric impression materials

Elastomeric impression materials (EIM) are primarily used for prosthodontic impressions. Four types of EIM are available: polysulfides, condensation silicones, addition silicones, and polyethers. These products are usually dispensed as two pastes or putties, which upon mixing begin to set into a firm, but elastic consistency. All EIM are set by catalyst-initiated polymerization and have been formulated to minimize shrinkage. The appropriate ratio of the pastes must be measured and spatulated in a manner that minimizes air entrapment to produce accurate impressions; therefore, many EIM are supplied in auto-mixing cartridges that

Box 21.11 The basic technique for making a dental impression with alginate

1. A rigid tray is designed so that the teeth and gingival margins are covered and so that 3–4 mm of material remains between the oral tissues and the tray. Overflow holes are drilled into the tray to allow material relief as the tray is placed.
2. The patient should be sedated to provide at least 10 minutes of access into the mouth without interference from the tongue or cheeks.
3. The mouth is thoroughly rinsed to remove feed material and to wet the teeth.
4. The impression tray is test-fitted.
5. The impression material is mixed according to the manufacturer's directions using a rubber bowl and spatula and then is spatulated into the impression tray.
6. The tongue, lips, and cheeks are retracted and controlled.
7. The tray is placed onto the teeth and held in position until the impression material sets. Setting can be approximated by leaving a small amount of material in the mixing bowl and observing the setting reaction.
8. The impression is gently removed and inspected for accuracy.
9. At least two impressions, preferably 3 or 4, should be made. You will want study and backup models in addition to the two working models sent to the dental laboratory.
10. Impressions should be wrapped in a damp cloth and stored in an air-tight container until the casts are poured.
11. Stone casts should be poured as soon as possible.

accurately measure and mix the pastes, on demand, and facilitate delivery into the impression tray or into the mouth. EIM have a working time of 2.5–7 minutes and a set time of 3–10 minutes. The expense of EIM is rarely commensurate with the degree of accuracy required for equine impressions; however, some equine practitioners commonly use EIM as temporary bandages to prevent food contamination of extraction site alveoli and periodontal pockets. EIM adapt well to the oral hard tissue walls and can be removed more easily than rigid acrylics, such as polymethylmethacrylate (PPMA). Condensation silicones (*silicone*, *silicone rubber*) have significant limitations compared to the other EIM and have lost popularity. The clinical properties of the other EIM will be briefly discussed.

The addition silicones (AS) (*polyvinyl siloxanes*, *polyvinyls*, *vinyls*) are currently the most popular impression materials for fixed prosthetics (Fig. 21.22). AS impressions have excellent detail and remain dimensionally stable for weeks. They are hydrophobic, and moisture (e.g., saliva, blood) can significantly degrade impression accuracy; therefore, AS must be used in a dry field. AS are thermally sensitive, and the rate of cure is accelerated by heating and decelerated by cooling. Several materials can contaminate AS, retarding polymerization and creating unacceptable impressions; therefore, rinsing the mouth with 2% chlorhexidine to remove contaminants before placing an AS impression is recommended. The most common contaminant is the sulfides in latex gloves; therefore, polyethylene gloves should be worn when handling AS. Other sources of contamination are recently placed restorative resins and the residual films left on the teeth by polyether and polysulfide impression materials.

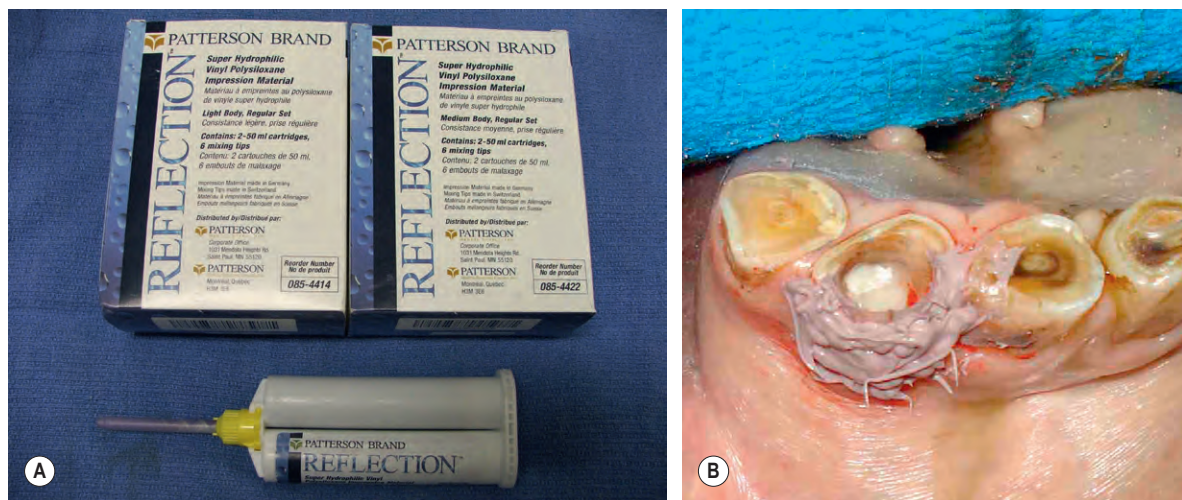


Fig. 21.22 Polyvinyl siloxane (PVS) is the most popular elastomeric impression material. (A) A generic material supplied in an auto-mixing cartridge. (B) PVS used as a mold for a resin composite restoration of a mandibular incisor. (Courtesy of Edward T. Early, DVM.)



Fig. 21.23 Alginate hydrocolloid impression materials. (A) Improvised incisor impression trays (right) and alginate impressions (left). (B) Making an alginate impression of the mandibular incisors in a sedated horse. (C) Improvised cheek teeth impression trays. (D) The alginate impressions of the mandibular cheek teeth.

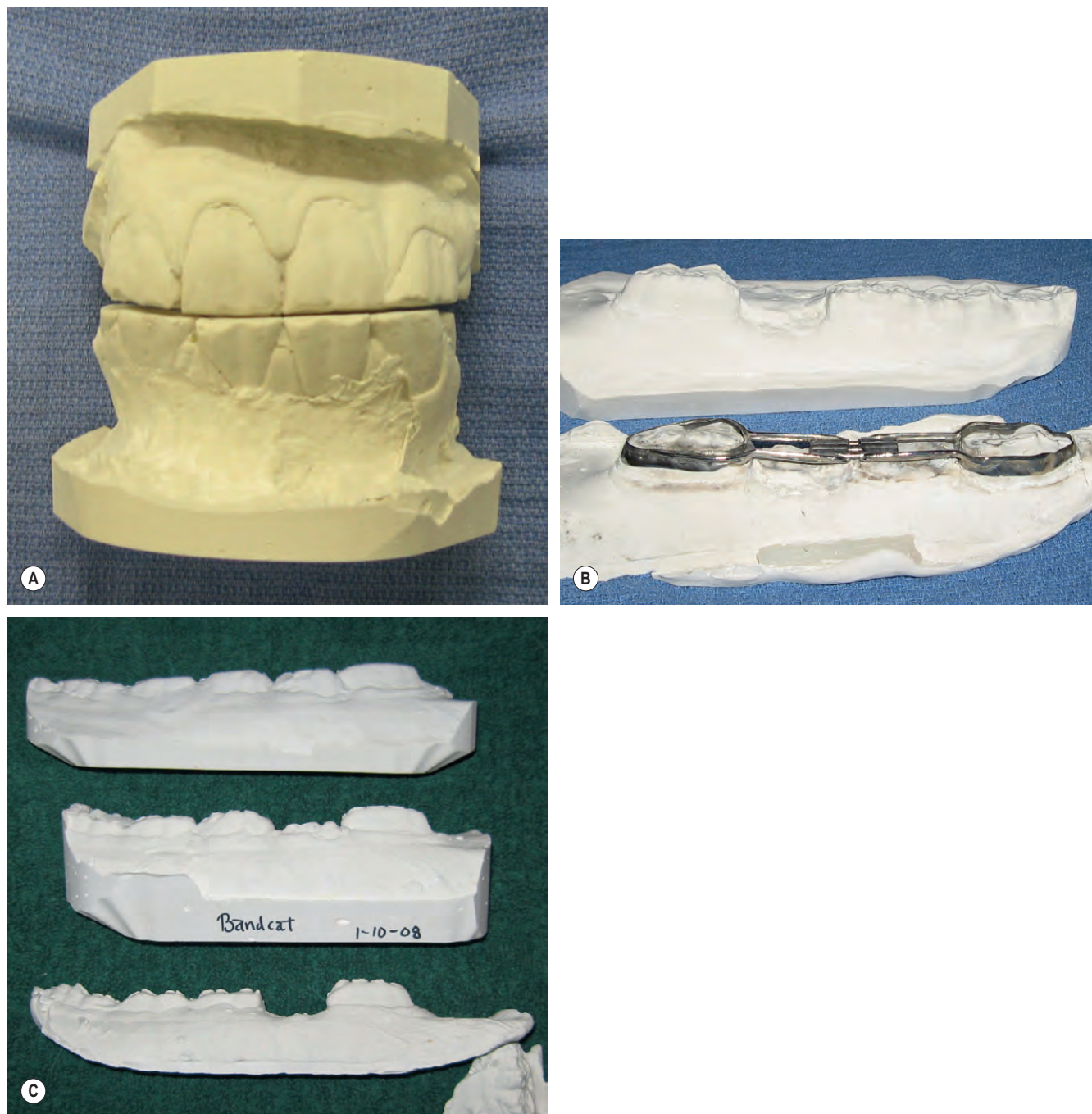


Fig. 21.24 Dental stone casts of the impressions from Fig. 21.23. (A) Casts of the incisors. (B) Working models of the mandibular cheek teeth used to construct an orthodontic appliance. (C) Study models of the mandibular cheek teeth used for treatment planning and for monitoring case progression.

Polyethers (PE) are the second most popular EIM, and the preferred material for full bite registrations. They produce impressions of excellent detail and retain dimensional stability for one to two weeks. PE are hydrophilic and make accurate impressions in a moist environment. The 'snap-set' behavior of PE allows the material to flow into an area during the entire working time and then rapidly set.

Polysulfides (PS) are also used for full-bite registrations in human dentistry. They are relatively inexpensive and make accurate impressions in a moist environment; however, the dimensional stability of PS is inferior to that of both AS and

PE. These materials are both temperature and moisture sensitive, and heat and humidity accelerate polymerization.

Alginate hydrocolloid impression materials

Alginate hydrocolloid impression materials (AHIM) are inexpensive and appropriate for dental impressions in equine patients. AHIM are dispensed as a powder containing soluble alginate (derived from marine plants), calcium sulfate dihydrate, and sodium phosphate. Upon mixing with water, alginic acid reacts with calcium sulfate to form an

insoluble elastic gel. Sodium phosphate retards the reaction and provides for the working time of the material. Tap water with high mineral content also retards the setting time. Fast-setting alginates (Type 1) have a 1–2 minute working time and are appropriate for use in sedated equine patients. Regular setting alginates (Type 2) have a 2–4.5 minute working time. AHIM are highly hydrophilic and should be applied in a moist field. Drying or polishing the pellicle off the teeth may cause the alginate to stick to the teeth. AHIM are easily removed from the mouth; however, their dimensional stability is short, and usually only one cast can be made from each impression. Ideally, casts should be poured within 15 minutes of making the impression; however, casting can be delayed until returning to the laboratory if the impressions are wrapped in a damp cloth and stored in an air-tight container. Although AHIM lack the detailed accuracy and the auto-mixing systems of EIM, they produce impressions of acceptable accuracy for diagnostic bite registrations and orthodontic models, at a fraction of the cost of EIM. Only gypsum casting materials can be used with alginate impressions (Fig. 21.23).

Cast materials

Dental plaster (plaster of Paris) and dental stone are used to fabricate dental casts from alginate impressions. Orthodontic casts are typically referred to as *models*. Both of these casting materials are made from gypsum (calcium sulfate dihydrate). The physical properties of the materials vary greatly based on the dehydration processes used to manufacture each material's base powder, calcium sulfate hemihydrate. The crystals of dental plasters (β -calcium sulfate hemihydrate) are large, irregularly shaped, and porous, whereas the crystals of dental stone (α -calcium sulfate hemihydrate) are

smaller, regularly shaped rods and prisms. Stone produces more detailed casts. However, both produce enough detail for orthodontic models and bite registrations in equine patients (Fig. 21.24).

Summary

Equine dentistry saw minimal change through most of the 20th century, with the disciplines of occlusal equilibration and exodontia being the standard of equine dental care. The resurgence of veterinary dental care in the 1990s stimulated practitioners to practice other dental disciplines (endodontics, orthodontics, periodontics, and restorative dentistry) in order to preserve the dentition of their patients. These disciplines require the application of dental materials.

The first decade of the 21st century has seen exponential changes in the practice of equine dentistry. Accepted dental procedures and material applications have been extrapolated from human and small animal veterinary dentistry for use in the equine patient, and anecdotal reports of success support the continuation of these practices. However, failures and the inappropriate application of dental materials demonstrate the need for scientific investigation. With continued case reporting by practitioners and clinical research by universities, our dental materials decisions will become evidence-based.

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Further reading

Anusavice KJ. Phillips' Science of Dental Materials, 11th ed. Saunders, St. Louis, 2003

Cohen S, Hargreaves KM, eds. *Pathways of the Pulp*, 9th ed. CV Mosby, St. Louis, 2006

Newman MG, Takei HH, Klokkevoeld PP, Carranza FA. Carranza's Clinical Periodontology, 10th ed. Saunders Elsevier, St. Louis, 2006

Powers JM, Sakaguchi RL, eds. Craig's Restorative Dental Materials, 12th ed. Mosby Elsevier, St. Louis, 2006

Wiggs RB, Lobprise HB, eds. *Veterinary Dentistry: Principles and Practice*. Lippincott-Raven, Philadelphia, PA, 1997

Zardiackas LD, Dellinger TM, Livingston M, eds. *Dental Clinics of North America, Dental Materials*. Saunders Elsevier, Philadelphia, PA, 2007

References

1. Harvey CE, Emily PP. Small animal dentistry. Mosby, St Louis, 1993, pp 215–232
2. Wiggs RB, Lobprise HB. Glossary of terms. In: Veterinary dentistry: principles and practice. Wiggs RB, Lobprise HB, eds. Lippincott-Raven, Philadelphia, 1993, p. 634
3. Taney KG. Composite restoration of enamel defects. J Vet Dent 2007; 24(2): 130–134
4. Bellows J. Small animal dental equipment, materials and techniques. Blackwell, Ames, Iowa, 2004, p. 129
5. Harvey CE, Emily PP. Small animal dentistry. Mosby Year Book, St Louis, 1993, p. 235
6. Wiggs RB, Lobprise HB, Hefferren JJ. Basic materials and supplies. In: Wiggs RB, Lobprise HB, eds. Veterinary dentistry: principles and practice. Lippincott-Raven, Philadelphia, 1997, p. 38
7. St. John KR. Biocompatibility of dental materials. Dent Clin N Am 2007; 51(3): 747–760
8. Brannan RD. Restorative Materials in Equine Dentistry. Annual Vet Dental Forum, 2005, pp 135–139
9. Rawls HR, Esquivel-Upshaw J. Restorative Resins. In: Anusavice KJ, ed. Phillips' Science of dental materials, 11th edn. Saunders, St Louis, 2003, p. 399
10. Kuijs RH, Fennis WM, Kreulen CM, et al. Does layering minimize shrinkage stresses in composite restorations? J Dent Res 2003 Dec; 82(12): 967–971
11. Chi HH. A posterior composite case utilizing the incremental and stratified layering technique. Oper Dent. 2006 Jul-Aug; 31(4): 512–516
12. Rawls HR, Upshaw JE. Restorative resins. In: Anusavice KJ, ed. Phillips' Science of

- dental materials, 11th edn. Saunders, St Louis, 2003, p. 2003
13. Klugh DO, Basil T, Brannan R. Infundibular decay in equine maxillary teeth. *J Vet Dent* 2001; 18(1) March: 26–27
 14. Earley ET. Restorative dentistry – applied restorative techniques and materials in the equine. In: *Proceedings of the 22nd Annual Veterinary Dental Forum*, Jacksonville, Florida, 2008, pp 141–162
 15. Stangel I, Ellis TH, Sacher E. Adhesion to tooth structure mediated by contemporary bonding systems. *Dent Clin N Am* 2007; 51(3): 677–694
 16. Miguez PA, Castro PS, Nunes ME, et al. Effect of acid-etching on the enamel bond of two self-etching systems. *J Adhes Dent* 2003; 5(2): 107–112
 17. Pneumans M, Kanumilli P, DeMunck J, et al. Clinical effectiveness of contemporary adhesives: a systemic review of current clinical trials. *Dent Mater* 2005; 21(9): 864–881
 18. Norling BK. Bonding. In: Anusavice KJ, ed. *Phillips' Science of dental materials*, 11th edn. Saunders, St Louis, 2003, p. 395
 19. Shen C. Dental Cements. In: Anusavice KJ, ed. *Phillips' Science of dental materials*, 11th edn. Saunders, St Louis, 2003, p. 476
 20. Shen C. Dental Cements. In: Anusavice KJ, ed. *Phillips' Science of dental materials*, 11th edn. Saunders, St Louis, 2003, p. 481
 21. Shen C. Dental Cements. In: Anusavice KJ, ed. *Phillips' Science of dental materials*, 11th edn. Saunders, St Louis, 2003, p. 484
 22. Baker NA, Eleazer PD, Averbach RE, et al. Scanning electron microscope study of the efficacy of various irrigation solutions. *J Endod* 1975; 1(4): 127–135
 23. Himel VT, McSpadden JT, Goodis HE. Instruments, Materials, and Devices. In: Cohen S, Hargreaves KM, eds. *Pathways of the pulp*, 9th edn. CV Mosby, St Louis, 2006, p. 252
 24. Baratt RM. Equine incisor endodontic therapy. In: *Proceedings of the 22nd Annual Veterinary Dental Forum*. Jacksonville, Florida, 2008, pp 113–123
 25. Rickles NH, Joshi BA. A death from air embolism during root canal therapy. *JADA* 1963; 67: 39
 26. Michael AH, Miserendino LJ. Instruments and Materials. In: Cohen S, Burns RC, eds. *Pathways of the pulp*, 4th edn. CV Mosby, Washington, DC, 1987, pp 397–440
 27. Mentz TCF. The use of sodium hypochlorite as a general endodontic medicament. *Int Endod J* 1982; 15: 132–136
 28. Ruddle CJ. Cleaning and shaping the root canal. In: Cohen S, Burns RC, eds. *Pathways of the pulp*, 8th edn. CV Mosby, St Louis, 2002, p. 258
 29. Cunningham WT, Balekjian AY. Effect of temperature on collagen-dissolving ability of sodium hypochlorite endodontic irrigant. *Oral Surg Oral Med Oral Path*, 1980; 49: 175
 30. Cunningham WT, Balekjian AY. Effect of temperature on the bactericidal action of sodium hypochlorite endodontic irrigant. *Oral Surg Oral Med Oral Path* 1980; 50: 569
 31. Svec TA, Harrison JW. The effect of effervescence on debridement of the apical region of root canals in single-rooted teeth. *J Endod* 1891; 7: 335–340
 32. Himel VT, McSpadden JT, Goodis HE. Instruments, materials, and devices. In: Cohen S, Hargreaves KM, eds. *Pathways of the pulp*, 9th edn. CV Mosby, St Louis, 2006, p. 260
 33. Peters OA, Peters CI. Cleaning and shaping the root canal. In: Cohen S, Hargreaves KM, eds. *Pathways of the pulp*, 9th edn. CV Mosby, St Louis, 2006, p. 346
 34. Evanov C, Liewehr FR, Buxton TB, Joyce AP. Antibacterial efficacy of calcium hydroxide and chlorhexidine irrigants at 37° and 46° C. *J Endod* 2004; 30: 653
 35. Zehnder M. Root canal irrigants. *J Endod* 2006; 32(5): 389–398
 36. Basrani BR, Manek S, Sodhi RN, et al. Interaction between sodium hypochlorite and chlorhexidine gluconate. *J Endod* 2007; 33: 966–969
 37. Rasimick BJ, Nekich M, Hladek MM, et al. Interaction between chlorhexidine digluconate and EDTA. *J Endod* 2008; 34(12): 1521–1523
 38. Grawehr M, Sener B, Waltimo T, Zehnder M. Interactions of ethylenediamine tetraacetic acid with sodium hypochlorite in aqueous solutions. *Int Endod J* 2003; 36: 411–417
 39. Safavi KE, Nichols FC. Effect of calcium hydroxide on bacterial lipopolysaccharide. *J Endod* 1993; 19(2): 76–78
 40. Peters OA, Peters C. Obturation of the cleaned and shaped canal. In: Cohen S, Hargreaves KM, eds. *Pathways of the pulp*, 9th edn. CV Mosby, St Louis, 2006, pp 372–375
 41. Senia ES, Marraro RV, Mitchell JL, et al. Rapid sterilization of gutta-percha cones with 5.25% sodium hypochlorite. *J Endod* 1975; 1: 136
 42. Himel VT, McSpadden JT, Goodis HE. Instruments, materials, and devices. In: Cohen S, Hargreaves KM, eds. *Pathways of the pulp*, 9th edn. CV Mosby, St Louis, 2006, p. 263
 43. Goodman A, Schilder H, Aldrich W. The thermomechanical properties of gutta-percha. IV. A thermal profile of the warm gutta-percha packing procedure. *Oral Surg Oral Med Oral Path* 1981; 51: 544
 44. Wiggs RB, Lobprise HB. Basic endodontic therapy. In: Wiggs RB, Lobprise HB, eds. *Veterinary dentistry: principles and practice*. Lippincott-Raven, Philadelphia, 1997, p. 317
 45. Stabholz A, Friedman S, Abed J. Marginal adaptation of retrograde fillings and its correlation with sealability. *J Endod* 1985; 11: 218–223
 46. Torabinejad M, Higa RK, McKendry DJ, Pitt Ford TR. Dye leakage of four root end filling materials: effects of blood contamination. *J Endod* 1994; 20: 159
 47. Adamo HL, Buruiana R, Schertzer L, Boylan RJ. A comparison of MTA, Super-EBA, composite, and amalgam as root-end filling materials using a bacterial microleakage model. *Int Endod J* 1999; 32: 197
 48. Torabinejad M, Wilder Smith P, Pitt Ford TR. Comparative investigation of marginal adaptation of mineral trioxide aggregate and other commonly used root end filling materials. *J Endod* 1995; 21: 295–299
 49. Shahriar S, Saeed R, Hamid RY, et al. Sealing ability of white and gray mineral trioxide aggregate mixed with distilled water and 0.12% chlorhexidine gluconate when used as root-end filling materials. *J Endod* 2007; 33: 1429–1432
 50. Pitt Ford TR, Torabinejad M, Abedi HR, et al. Using mineral trioxide aggregate as a pulp-capping material. *J Am Dent Assoc* 1996; 127: 1491–1494
 51. Faraco IM Jr, Holland R. Response of the pulp of dogs to capping with mineral trioxide aggregate or a calcium hydroxide cement. *Dent Traumatol* 2001; 17: 163–166.
 52. Apaydin ES, Shabahang S, Torabinejad M. Hard tissue healing after application of fresh or set MTA as root-end filling material. *J Endod* 2004; 30: 21
 53. Torabinejad M, Hong CUI, Lee SJ, et al. Investigation of mineral trioxide aggregate for root-end filling in dogs. *J Endod* 1995; 21: 603
 54. Torabinejad M, Pitt Ford TR, McKendry DJ, et al. Histological assessment of mineral trioxide aggregate as root-end filling in monkeys. *J Endod* 1997; 23: 223–225
 55. Earley ET. Pulp disease in mandibular cheek teeth. In: *Proceedings of the 20th Annual Veterinary Dental Forum*, Portland, Oregon, 2006, pp 117–126
 56. Bellows J. *Small Animal Dental Equipment, Materials and Techniques*. Blackwell, Ames, Iowa, 2004, p. 134
 57. Jahn C. Supragingival and subgingival irrigation. In: Newman MG, Takei HH, Klokkevold PP, Carranza FA, eds. *Carranza's Clinical periodontology*, 10th edn. Elsevier, St Louis, 2006, p. 842
 58. Stashak TS. *Equine Wound Management*. Williams and Wilkins, Baltimore, 1991, p. 116

59. Morrison SL, Cobb CM, Kazakos GM, et al. Root surface characteristics associated with root surface placement of monolithic tetracycline-impregnated fiber. *J Periodontol* 1992; 63: 137
60. Wiggs RB, Lobprise HB. Periodontology. In: Wiggs RB, Lobprise HB, eds. *Veterinary dentistry: principles and practice*. Lippincott-Raven, Philadelphia, 1997, p. 225
61. Klugh DO. Equine periodontal disease. *Clin Technique Equine Pract* 2005; 4: 135–147
62. Bellows J. Small animal dental equipment, materials and techniques. Blackwell, Ames, Iowa, 2004, p. 136
63. Wiggs RB, Lobprise HB. Periodontology. In: Wiggs RB, Lobprise HB, eds. *Veterinary dentistry: principles and practice*. Lippincott-Raven, Philadelphia, 1997, p. 224
64. Vitale MC, Caprioglio C, Martignone A, et al. Combined technique with polyethylene fibers and composite resins in restoration of traumatized anterior teeth. *Dent Traumatol* 2004; 20: 172–177
65. Klugh DO. A review of equine periodontal disease. In *Proceedings, AAEP Annual Convention, 2006*; 52: 551–558
66. Spear FM, Cooney JP. Restorative interrelationship. In: Newman MG, Takei HH, Klokkevold PP, Carranza FA, eds. *Carranza's clinical periodontology*, 10th edn. Elsevier, St Louis, 2006, p. 1065
67. Precheur HV. Bone graft materials. In: Zardiackas LD, Dellinger TM, Livingston M, eds. *Dent Clin N Am* 2007; 51(3): 734
68. Jahn C. Supragingival and subgingival irrigation. In: Newman MG, Takei HH, Klokkevold PP, Carranza FA, eds. *Carranza's Clinical periodontology*. 10th edn. Elsevier, St Louis, 2006, p. 982
69. Deforge DH. Evaluation of Bioglass/PerioGlas (Consil) synthetic bone graft particulate in the dog and cat. *J Vet Dent* 1997; 14(4): 141–145
70. Allen I, Newman H, Wilson M. Antibacterial activity of particulate bioglass against supra- and subgingival bacteria. *Biomaterials* 2001; 22: 1683–1687
71. Kim CK, Kim HY, Chai JK, et al. Effect of a calcium sulfate implant with calcium sulfate barrier on periodontal healing in 3-wall intrabony defects in dogs. *J Periodontol* 1998; 69: 982
72. Wiggs RB, Lobprise HB. Basic materials and supplies. In: Wiggs RB, Lobprise HB, eds. *Veterinary dentistry: principles and practice*. Lippincott-Raven, Philadelphia, 1997, p. 38
73. Carranza FA, Takei HH, Cochran DL. Reconstructive periodontal surgery. In: Newman MG, Takei HH, Klokkevold PP, Carranza FA, eds. *Carranza's Clinical periodontology*, 10th edn. Elsevier, St Louis, 2006, p. 982
74. Vlamincck L, Cnudde V, Pieters K, et al. Histologic and micro-computed tomographic evaluation of the osseointegration of a nonresorbable bone substitute in alveoli of ponies after tooth extraction. *Am J Vet Res* 2008; 69: 604–610

Endodontic therapy

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Introduction

Endodontics, from the Greek *endo* (inside) and *odons* (tooth), is a specialist sub-field of dentistry that deals with the treatment of the tooth pulp and the tissues surrounding the apex of a tooth. In contrast to exodontia, endodontic treatment is aimed at the preservation of teeth affected with pulp or apical infection. In man, dental caries and dental trauma are the most common causes of acute pulpitis.¹ Because equine dentition is anatomically very different from human, canine or feline teeth,^{2–5} endodontic techniques that are well established in such brachydont species have to be critically evaluated before they can be applied in equine (hypsodont) teeth.

Anachoresis, fissure and gross idiopathic fractures; external traumatic fractures; extension of periodontal disease, and extension of infundibular caries have been described as the most common causes of apical infection in the horse,^{1,6,7} and the etiopathogenesis of these disorders is discussed more fully in Chapters 9 and 10. Direct exposure of pulp, or reduction of dentin so close to the pulp as to effectively expose it, can occur during equine dental procedures. Excessive heat production by power equipment during routine dental corrections or diastema widening can also cause thermal pulpitis or even pulp necrosis.⁸

Acute pulp exposure

As noted above, vital pulp can be exposed secondary to dental fractures^{9–11} or iatrogenically during dental procedures. Dental fractures are not always recognized by horse owners because some affected horses do not show obvious signs of dental pain. Whether the equine species is less susceptible to dental pain or the suppression of pain is a simple phylogenetic necessity in horses, in order not to stand out as prey, remains unclear. Due to absence of signs of dental pain in some horses, idiopathic fractures with pulp exposure are often not detected or treated immediately, and some fractured teeth spontaneously heal by deposition of tertiary dentin on the occlusal aspect of the exposed pulps, as discussed in Chapter 10. Any deficits in this natural repair mechanism result in extension of the pulpitis with probable development of apical abscess formation, or pulp necrosis. Only a small percentage of horses with idiopathic fractures

develop acute masticatory problems, fever, or swelling of the supporting bones. When recent dental fractures are diagnosed, the resultant pulp exposure can be managed as described below. At present, dental extraction is still the therapy of choice in the majority of sub-acute or chronic apically infected cheek teeth.¹² In selected cases, affected teeth may be preserved with endodontic techniques, such as vital pulpotomy, where a sufficiently viable pulp is saved, or alternatively, by apical resection with pulpectomy (extirpation of pulp).^{1,12,13}

As noted above, acute pulp exposure can occur accidentally during routine dental procedures, in particular during the reduction of incisor overgrowths, including mandibular or maxillary pro- or brachygnathism overgrowths, 'slant-mouth' (diagonal bite), and during reduction of canines (Fig. 22.1) or cheek teeth overgrowths ('hooks', 'ramps', 'tall teeth', wave- and step-mouth formation). Such iatrogenic pulp exposure actually occurs more often than is currently assumed.¹ It has been claimed that pulp exposure under such conditions does not require treatment because the normal deposition of reparative dentin is adequate, and no complications result from pulp exposure in equine teeth. These suppositions are due largely to lack of observation.¹ A recent study found the depth of secondary dentin in equine cheek teeth to be highly variable, ranging from 2.5 to 15 mm, and consequently the distance from the occlusal surface to the vital pulp is unpredictable in normal teeth.¹⁴

The consequence for the equine dental practitioner is that pulp exposure may be detected at any time, especially when performing dental procedures. It is desirable that some equine veterinarians have a theoretical knowledge of endodontics as well as the practical skills and adequate equipment to enable satisfactory management of pulpar exposure.

Diagnosis

The diagnosis of iatrogenic pulp exposure can be difficult in some cases, especially when it occurs in caudal cheek teeth. Nevertheless, the detection and adequate management of iatrogenic pulp exposure are the responsibility of all equine dental practitioners. A final examination at the end of any dental correction using a mirror or an endoscope^{15,16} is mandatory to detect iatrogenically exposed pulp cavities.

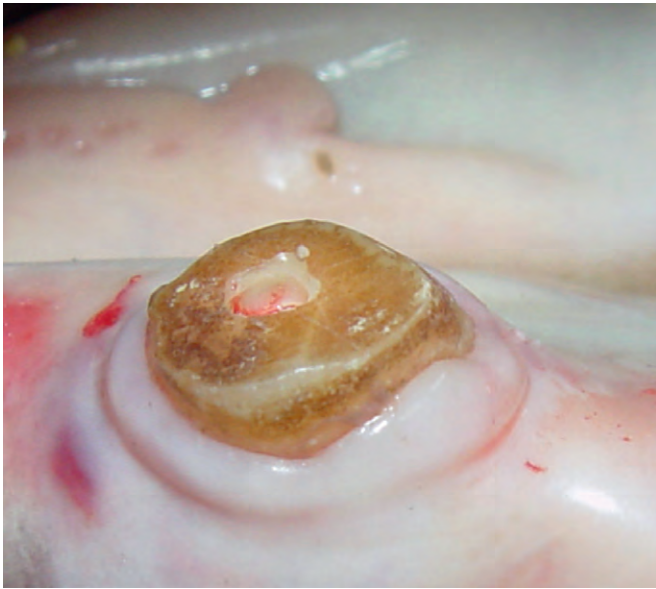


Fig. 22.1 An open pulp cavity in a left lower canine (Triadan 304) caused by excessive reduction of the tooth, following debridement and hemorrhage control.

Bleeding from freshly opened pulp cavities may subside quickly, especially in older animals with narrow pulp horns. Consequently, major dental reductions should be performed slowly in stages, interrupted by examinations of the occlusal surface with a mirror or endoscope. The use of power equipment for dental correction creates a dough-like, viscous layer of wet dental dust which can temporarily occlude pulp cavities, thus masking pulpar exposure. Consequently, dental debris should be flushed from the occlusal surface before examining the occlusal surface.

Management of pulpar exposure

In the case of dental fractures, X-rays should be taken to evaluate the full extent of the fracture, including assessment of the supporting bones. If the extent of the fracture does not preclude dental preservation, preparations for endodontic surgery, (that can be performed in the standing, sedated horse) can proceed. Local analgesia via blocking of the ipsilateral maxillary or mandibular nerve significantly facilitates these endodontic procedures.¹⁷ General anesthesia is only required in a minority of cases, including those occasions when adequate local analgesia cannot be obtained.

Initially, loose dental fragments are removed from fractured teeth (Fig. 22.2), and then 2–3 mm of the clinical crown should be removed if the affected tooth is still in occlusal contact, to avoid occlusal pressure from the opposing teeth for a minimum of 2–3 months.¹ Bleeding resulting from these procedures can be controlled using locally applied hemostyptic drugs (e.g., adrenaline) or electro-surgical devices.

A fine, sterile dental pick should now be used to gently probe the open pulp cavity. Bleeding indicates the likely presence of vital (may be inflamed or infected beyond redemption) pulp tissue and thus a chance of preserving the tooth. In order to avoid additional trauma to the pulp, the



Fig. 22.2 Contaminated traumatic fractures of 202, and 203.

probe is then retracted, and the distance between the occlusal surface of the fracture and the underlying viable pulp is measured. High-speed dental burs or spoon excavators should now be used to enlarge the pulp cavity¹ in order to create better access to the diseased pulp. Simultaneously, contaminated dentin lining the walls of the pulp chambers is removed with a dental burr. This procedure can be difficult in curved incisor root canals. In this instance, the pulp cavity can be accessed from an opening in the intact labial aspect of the clinical crown, which enables a straight drill plane path to be achieved.¹²

The tooth should be thoroughly disinfected, and the burr should be sharp and clean (new – preferably sterile). When the surgeon is drilling into an exposed pulp, bleeding indicates that the vital pulp has been reached, and drilling should be extended for some additional millimeters if possible to remove any adjacent diseased pulp.

The exposed pulp canal should be shaped like an inverse cone (undercut) close to the occlusal surface to prevent later loss of filling material. The exposed canal is then carefully cleaned using Ringer's solution and sterile paper points. Clean (preferably sterile) compressed air can also be used to dry the pulp canal, but drying of the pulp must be avoided. Hemostasis is subsequently performed using small cotton pellets or paper points soaked in adrenaline (Fig. 22.3). A couple of minutes after the bleeding has stopped, the pellets are removed carefully, and the pulp can now be capped with calcium hydroxide or similar materials. Calcium hydroxide (Ca(OH)_2), which is used in paste form (calcium hydroxide and sterile water) in this situation, has a strong antimicrobial effect¹⁸ (due to its basic pH) and also acts as a tertiary dentin stimulant. It is preferable to cover softer, water-based calcium hydroxide with resin-containing calcium hydroxide such as Dycal, but it is inadvisable to place resin-containing preparations directly on to pulp. In human dentistry, other products, such as MTA (mineral trioxide aggregate) are used.¹⁹ MTA is a biocompatible endodontic cement that is also capable of stimulating healing and dentogenesis and sets in the presence of moisture.²⁰

In the horse, provided occlusal contact is avoided, additional restorative covers may not be necessary over the

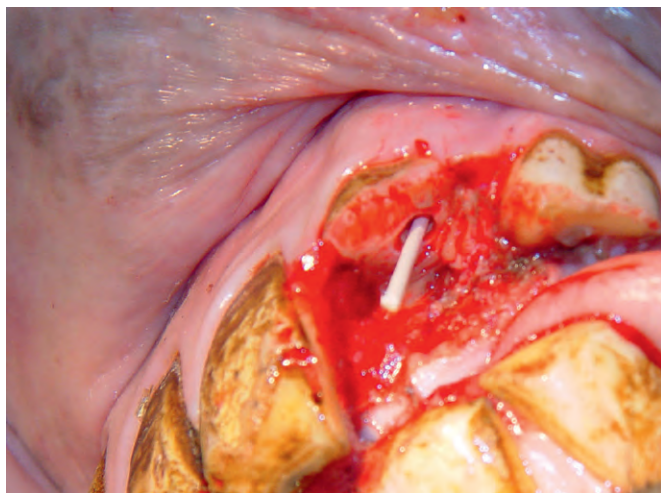


Fig. 22.3 Same horse as in Fig. 22.2. The fracture fragments and debris have been removed; the pulp canal of 202 has been drilled and curetted, and a paper point soaked in 0.8% adrenaline solution is inserted into its pulp cavity for hemostasis. Filling with calcium hydroxide paste will now be performed.



Fig. 22.5 Same horse as in Fig. 22.4. All visible infected and discolored dental tissues have been removed with a diamond burr. The pulp canals have also been debrided and pulpotomy has been performed. Calcium hydroxide paste will now be applied.



Fig. 22.4 Longstanding (note necrosis of circumpulpal dentin) traumatic fractures of 101 and 201 in a 7-year-old horse. The fractured teeth have been cleaned. An isolated fracture fragment lying between 101 and 102 has been left *in situ* in order to prevent excessive local hemorrhage prior to endodontic therapy.



Fig. 22.6 Parapulpal pins have been placed into the dentin of the endodontically treated incisors to facilitate partial reconstruction of the crowns.

calcium hydroxide,¹ especially if covered with a resin-containing calcium hydroxide preparation. Alternatively, the more occlusal endodontic calcium hydroxide cement can be removed, and a few millimeters of the root canal close to the masticatory surface can be sealed with glass ionomere²¹ or a resin-composite endodontic material. In show horses, incisors that are fractured at gingival level can be reconstructed using parapulpal pins and composite (Figs 22.4–22.7) to avoid protrusion of the tongue. The owners should be informed that the reconstructed crown has to be reduced at intervals to prevent occlusal contact with the opposite incisor; otherwise the artificial crown will inevitably break as human parapulpal pins and composite cannot withstand the forces of equine prehension. Owners should also be

advised not to feed hay from nets, in order to reduce forces on the incisor restorations.

Endodontic procedures in apically infected cheek teeth

Oral approach

Whilst the technique described above can easily be performed in equine incisors, pulp canal treatment of infected cheek teeth using an intraoral approach is significantly more demanding due to difficulties in visualization and limited access to the equine oral cavity. Long-handled instruments and long-shafted, angled dental drills are required, as well as dental mirrors or, preferably, a 90° oral endoscope to visualize the surgical site. A skilled assistant is needed to



Fig. 22.7 Partial reconstruction of the crowns. Several layers of self curing composite have been attached to the parapulpal pins. The artificial crowns do not reach the occlusal surface of the opposing mandibular incisors. Finally the composite is polished and the dental fracture fragment is removed.

direct the endoscope, if the procedure is performed under direct video control. If the procedure is performed by a single surgeon, the use of a dental burr has to be alternated with use of other instruments and/or visual control.

Although the endodontic treatment of cheek teeth using an intraoral approach is often discussed anecdotally at dental conferences, no scientific studies or objective long-term reports on the outcome of such attempts appear to have been published to date on this technique. Indeed, when one considers the length (up to 10 cm) which might be required to instrument an equine pulp canal, in relation to the space available when the mouth is fully open, such an approach is often likely to be impracticable.

Apical approach (apicoectomy)

Apicoectomy (radiculectomy) of equine cheek teeth has been described by several authors.^{1,13,22–25} Apicoectomy involves the resection of the tooth apex, followed by removal of the affected pulps and sealing of the pulp canal system to remove any possible communication between the oral cavity and the periapical tissues.²⁵ Careful case selection of cases for such endodontic surgery is mandatory. A thorough oral examination (see Ch.12) in conjunction with high quality radiographs²⁶ and/or computed tomography (Ch. 13) are required to identify suitable cases. Teeth showing signs of extensive periodontal disease, large fractures, evidence of dental decay, multiple pulpar exposure or long-standing apical infection (with subsequent tooth demineralization) are unsuitable for endodontic surgery.¹³ In such cases, dental extraction should be recommended.

The apicoectomy technique used by the author has been recently described.¹³ Surgery is usually performed under general anesthesia with the patient in lateral recumbency. To definitively identify the site of the affected apex, intra-operative radiography, using surface or sinus tract metallic markers should be performed. Access to the affected cheek teeth apices is gained, either via trephination²⁷ for

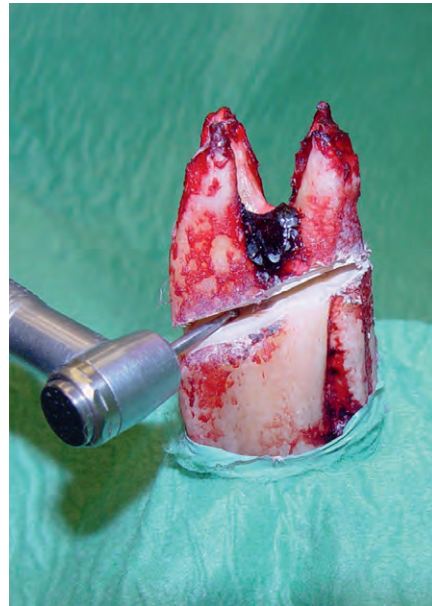


Fig. 22.8 Apicoectomy is demonstrated in the following figures using an extracted maxillary cheek tooth to allow better visualization. The apices are removed with a diamond-coated burr. (Reproduced from Simhofer H, Stoian C, Zetner K. A long-term study of apicoectomy and endodontic treatment of apically infected cheek teeth in 12 horses. *Vet J* 2008; 178: 411–418. With courtesy of the editor.)¹⁴

mandibular and rostral maxillary cheek teeth, or via a maxillary bone flap for more caudal maxillary cheek teeth. Bacteriological samples should be taken from the infected periapical regions to allow effective postoperative antimicrobial therapy. The infected apical region is then debrided, and infected tissue is removed using curettes. The surgical site can be obscured by hemorrhage, and even moderate bleeding significantly prolongs surgery and can compromise the quality of root canal sealing. Packing the hemorrhaging area with gauze or bone wax,²⁵ the use of local vasoconstrictors, such as adrenaline solution (0.8%), and continuous suction¹³ can keep the apical area blood-free during endodontic treatment.

Diamond burs mounted on a sterile, high-speed dental drill are used to resect the apex of the affected tooth. Constant irrigation with sterile Ringer's solution throughout the procedure is essential to prevent heat damage of adjacent dental tissues. The apex is cut at an angle of 15°–20° in a buccolingual (or buccopalatal) plane, so that the cut surface faces buccally (Fig. 22.8). All five (or six) pulp canals are then visualized and enlarged with a conical diamond burr. The contents of the pulp canals (necrotic, infected, or healthy pulps, or food material) are then removed as completely as possible using barbed broaches (Fig. 22.9). In contrast to vital pulps, which are easily removed in one piece, debridement of necrotic pulp debris and cleansing of infected pulp canals are frequently time-consuming and technically difficult. Nevertheless these procedures must be meticulously performed on all affected root canals. The empty canals are then filed with Hedström files of ascending diameter to remove infected and carious circumpulpal dentin, and the pulp canals are alternately flushed with 2.5% sodium hypochlorite and 3% hydrogen peroxide solutions until no

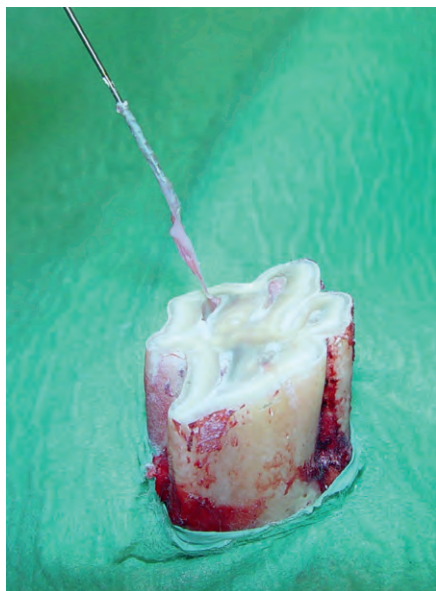


Fig. 22.9 The pulps are extracted using a barbed broach. (Reproduced from Simhofer H, Stoian C, Zetner K. A long-term study of apicoectomy and endodontic treatment of apically infected cheek teeth in 12 horses. *Vet J* 2008; 178: 411–418. With courtesy of the editor.)¹⁴



Fig. 22.11 The pulp canals are dried using paper points and compressed air. (Reproduced from Simhofer H, Stoian C, Zetner K. A long-term study of apicoectomy and endodontic treatment of apically infected cheek teeth in 12 horses. *Vet J* 2008; 178: 411–418. With courtesy of the editor.)¹⁴



Fig. 22.10 The pulp horns are flushed with sodium hypochlorite. (Reproduced from Simhofer H, Stoian C, Zetner K. A long-term study of apicoectomy and endodontic treatment of apically infected cheek teeth in 12 horses. *Vet J* 2008; 178: 411–418. With courtesy of the editor.)¹⁴



Fig. 22.12 Gutta percha points are used to compress endodontic cement deep into the pulp canals. (Reproduced from Simhofer H, Stoian C, Zetner K. A long-term study of apicoectomy and endodontic treatment of apically infected cheek teeth in 12 horses. *Vet J* 2008; 178: 411–418. With courtesy of the editor.)¹⁴

further debris or discolored dentin shavings are extracted from the canal (Fig. 22.10). The final pulp canal flush is performed with 70% ethyl alcohol. The pulp canals are then dried using pressurized air and paper points (Fig. 22.11).

A variety of materials, such as human dental eugenol-based or eugenol-free cements, gutta percha or composite endodontic materials have been used for filling empty pulp canals^{13,20–24,28} (Fig. 22.12). The choice of endodontic filling material in equine teeth influences the long-term success of

the procedure. Teeth on which apicoectomy has been performed continue to erupt (dental eruption is unaffected by endodontic procedures) and are consequently subjected to normal attrition. As all pulps have been removed during surgery, these teeth have lost the ability to produce secondary dentin which normally prevents occlusal pulpar exposure. Consequently, with continued eruption of the treated tooth, the endodontic filling material eventually appears at the occlusal surface after the remaining subocclusal secondary



Fig. 22.13 An undercut is created in the apical aspects of the pulp canals using a diamond-tipped burr on a high-speed dental drill. (Reproduced from Simhofer H, Stoian C, Zetner K. A long-term study of apicoectomy and endodontic treatment of apically infected cheek teeth in 12 horses. *Vet J* 2008; 178: 411–418. With courtesy of the editor.)¹⁴



Fig. 22.14 Apical sealing is performed using glass ionomer cement. (Reproduced from Simhofer H, Stoian C, Zetner K. A long-term study of apicoectomy and endodontic treatment of apically infected cheek teeth in 12 horses. *Vet J* 2008; 178: 411–418. With courtesy of the editor.)¹⁴

dentin (if present) is worn away. Human endodontic filling materials are not designed to withstand any abrasion whatsoever and so cannot withstand the abrasive forces of equine mastication and so are gradually lost when the material is occlusally exposed. Consequently, food material becomes compressed into the pulp canals which eventually can cause dental decay, secondary fractures, or apical re-infection. The use of filling materials with higher abrasive resistance, such as resin-composite endodontic materials, should lead to better long-term results. Such materials are not designed for obturation of pulp canals, so their performance when so used, especially in the high volume of the equine pulp canal, has yet to be established. In particular, shrinkage which breaks the initial seal may be a problem. The best choice of material for equine apicoectomy is as yet uncertain.

Adequate sealing of the resected apex has also been reported to have a major influence on the outcome of equine apicoectomies.^{21,28} To prevent the loss or disintegration of the apical seal, it is strongly recommended that an undercut is made with diamond-coated burs on the apical aspect of each root canal (Fig. 22.13). Apical sealing can then be performed with self-curing, glass ionomer cement, amalgam, MTA or, less satisfactorily, with a resin-based calcium hydroxide cement (Fig. 22.14). Postoperative radiographs should be taken at this stage (Fig. 22.15) to ensure adequate pulp canal sealing is present.²⁹ The surgical wound is closed in routine fashion. Antibiotic and anti-inflammatory drugs are administered for 3–5 days postoperatively.

With careful case selection, success rates of about 80% have been described.^{1,13} Reasons for failure of this technique include spread of infection from infected to unaffected pulps via communicating pulp canals, especially in young horses.³⁰ No current diagnostic technique appears to enable a clear differentiation between infected and uninfected pulps prior

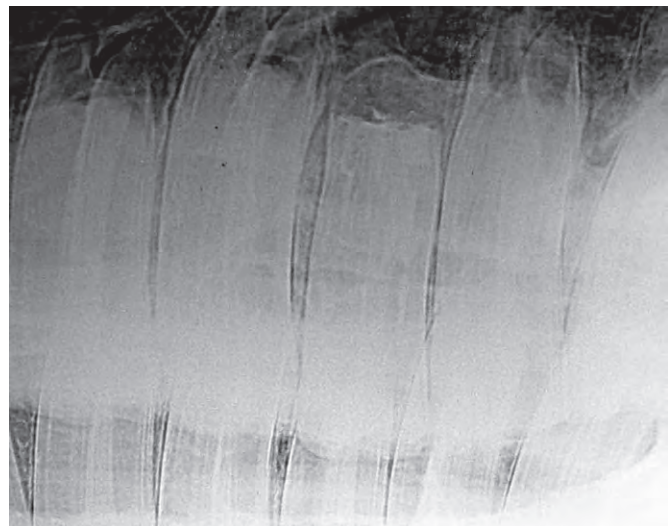


Fig. 22.15 Postoperative X-ray of a 5-year-old Quarterhorse gelding after apical resection and endodontic treatment of 109. (Reproduced from Simhofer H, Stoian C, Zetner K. A long-term study of apicoectomy and endodontic treatment of apically infected cheek teeth in 12 horses. *The Vet J* 2008; 178: 411–418. With courtesy of the editor.)¹⁴

to surgery, and so all pulp should be removed. In the future, magnetic resonance imaging may provide precise information on the health status of individual pulps.³¹

Despite the fact that equine endodontic surgery is a sophisticated, costly, and currently controversially technique, the successful outcome of a comparatively high percentage of cases treated to date warrants further objective long-term studies *in vitro* and *in vivo* to increase our knowledge of this potentially useful technique.

References

- Baker GJ. Endodontic therapy. In Baker GJ, Easley J, eds. *Equine dentistry*, 2nd edn. Elsevier, Edinburgh, 2005, pp 295–302
- Masson E, Hennet P, Calas P. Apical root canal anatomy in the dog. *Endodontics and dental traumatology* 1992; 8: 109–112
- Rochette J. Identification of the endodontic system in carnassial and canine teeth in the dog. *J Vet Dent* 1996; 13: 35–39
- Verstraete FJM, Terpak CH. Anatomical variations in the dentition of the domestic cat. *J Vet Dent* 1997; 14: 137–140
- Hernández SZ, Negro VB, Maresca BM. Morphologic features of the root canal system of the maxillary fourth premolar and mandibular first molar in dogs. *J Vet Dent* 2001; 18: 9–13
- Dacre I, Kempson S, Dixon PM. Pathological studies of cheek teeth apical infections in the horse part 4: aetiopathological findings in 41 apically infected mandibular cheek teeth. *Vet J* 2008 Dec; 178(3): 341–351
- Dacre I, Kempson S, Dixon PM. Pathological studies of cheek teeth apical infections in the horse part 5: aetiopathological findings in 57 apically infected maxillary cheek teeth and histological and ultrastructural findings in apically infected cheek teeth. *Vet J* 2008 Dec; 178(3): 352–363
- Allen ML, Baker GJ, Freeman DE, et al. In vitro study of heat production during power reduction of equine mandibular teeth. *J Am Vet Med Assoc* 2004; 224: 1128–1132
- Dacre I, Kempson S, Dixon PM. Equine idiopathic cheek teeth fractures. Part 1 pathological studies on 35 fractured cheek teeth. *Equine Vet J* 2007; 39: 310–318
- Taylor L, Dixon PM. Equine idiopathic cheek teeth fractures part 2: a practice-based survey of 147 affected horses in Britain and Ireland. *Equine Vet J* 2007; 39: 322–326
- Dixon PM, Barakzai SZ, Collins NM, Yates J. Equine idiopathic cheek teeth fractures part 3: a hospital-based survey of 68 referred horses (1999–2005). *Equine Vet J* 2007; 39: 327–332
- Garcia F, Sanromán F, Llorens MP. Endodontics in horses. An experimental study. *Zentralblatt Veterinaermedizin. Reihe A* 1990; 37: 205–214
- Simhofer H, Stoian C, Zetner K. A long-term study of apicoectomy and endodontic treatment of apically infected cheek teeth in 12 horses. *Vet J* 2008; 178: 411–418
- Wiegandt C. Veterinary thesis, Vienna, 2008
- Tremaine H. Dental endoscopy in the horse. *Clinical Techniques in Equine Practice* 4, 2005, pp 181–187
- Simhofer H, Griss R, Zetner K. The use of oral endoscopy for detection of cheek teeth abnormalities in 300 horses. *Vet J* 2008 Dec; 178(3): 396–404
- Staszyk C, Bienert A, Bäumer W, et al. Simulation of local anaesthetic nerve block of the infraorbital nerve within the pterygopalatine fossa anatomical landmarks defined by computed tomography. *Research in Veterinary Science* 2008; 85: 399–406
- Gomes BPFdA, Ferraz CCR, Vianna ME, et al. In vitro antimicrobial activity of calcium hydroxide pastes and their vehicles against selected microorganisms. *Br Dent J* 2002; 13: 155–161
- Carrotte P. Endodontics Part 9. Calcium hydroxide, root resorption, endo-perio lesions. *Br Dent J* 2004; 197: 735–743
- Tanomaru MJMG, Barros DB, Watanabe E, Ito IY. In vitro antimicrobial activity of endodontic sealers, MTA-based cements and Portland cement. *J Oral Sci* 2007; 49: 41–45
- Pretorius S, van Heerden WF. The use of tricure glass ionomer cement as an apical sealant after apicoectomy. *Journal of the South African Dental Association* 1995; 50: 360–370
- Van Foreest AW, Wiemer P. Veterinary dentistry. Apex resection in the horse. *Tijdschrift voor diergeneeskunde* 1997; 122: 670–679
- Van den Bogaard A. Apex resection in horses. *Tijdschrift voor diergeneeskunde* 1998; 123: 84–85
- Zetner K, Fahrenkrug P. Indikation, Technik und Prognose der Wurzelspitzenresektion im Pferdegebiss. *Proceedings. Jahreskongress des Bundesverbandes der praktischen Tierärzte, Nürnberg, 1999*
- Schramme MC, Boswell JC, Robinson J, et al. Endodontic therapy for periapical infection of cheek teeth a study of 19 horses. In *Proceedings of the 46th Annual Convention of the American Association of Equine Practitioners, 2000*, pp 113–116
- Barakzai SZ. Radiology and scintigraphy techniques and normal and abnormal findings. *Proceedings Focus on Equine Dentistry. American Association of Equine Practitioners, Indianapolis. 2006*, pp 168–172
- Barakzai SZ, Kane-Smyth J, Lowles J, Townsend N. Trephination of the equine rostral maxillary sinus: efficacy and safety of two trephine sites. *Veterinary Surgery* 2008; 37: 278–282
- Steenkamp G, Olivier-Carstens A, van Heerden WF, et al. In vitro comparison of three materials as apical sealants of equine premolar and molar teeth. *Equine Vet J* 2005; 37: 133–136
- Carr G, Bentkover S. Surgical endodontics. In: Cohen S, Burns R, eds. *Pathways of the pulp*, 7th edn. Mosby, St Louis, 1998, pp 608–656
- Klugh D. Unpublished data, 2003. Cited by Dacre, 2003
- Gerlach K. Die Darstellung von Pferde Zähnen und benachbarter Strukturen im MRT einschließlich deren Entwicklung und Erkrankungen-derzeitiger Stand. *Proceedings of the 6th Annual meeting of the IGFP 8–9 March, Frankfurt, Germany, 2008*

The temporomandibular joint

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Introduction

Disorders of the temporomandibular joint (TMJ) are common in human beings, having a reported prevalence of up to 80%.¹ In contrast, reports of horses affected with disease of the TMJ are sparse and are limited to reports of horses with advanced disease, perhaps not because the prevalence of the disease is low, but because definitively diagnosing disease of the TMJ of horses is difficult. In this chapter, we describe the anatomy and function of the TMJ, diseases of the TMJ, and options for medical and surgical management of horses affected with disease of the TMJ.

Anatomy

The equine TMJ is a synovial joint formed by the zygomatic process of the temporal bone and the condylar process, or condyle, of the mandible (Fig. 23.1).^{2,3} It is an incongruent joint and is divided completely into two separate compartments by an L-shaped, centrally concave, fibrocartilaginous disc (Fig. 23.1).^{2,4–7} The disc attaches circumferentially to the mandibular condyle, temporal bone, and joint capsule.^{5,6} The dorsal, discotemporal compartment is wider than the ventral, discomandibular compartment and apparently does not usually communicate with it,^{2,4–8} though in one study, communication between the compartments was demonstrated in three of seven cadaver heads injected with dye, indicating that in at least a small percentage of horses, they do communicate.⁹ Each compartment has a rostral and a caudal recess. The caudal recess of the discotemporal compartment is larger than the rostral recess, and the rostral recess of the discomandibular compartment is larger than the caudal recess.^{5,6,8} The joint capsule is reinforced by the lateral and caudal ligaments.^{5,6,8}

Muscles of mastication associated with the equine TMJ include the temporalis muscle, which attaches to the medial and rostral aspects of the joint capsule, the masseter muscle, which attaches rostrally and laterally to the joint capsule, and the lateral and medial pterygoid muscles, which attach laterally and medially to the joint capsule.^{3,5,6}

The blood supply to the TMJ arises from the transverse facial, superficial and deep temporal, and tympanic arteries.⁵

The transverse facial vessels pass ventral to the TMJ, and the superficial temporal artery and vein run caudal to the TMJ. The zygomatic branch of the auriculopalpebral nerve passes caudal and dorsal to the TMJ to reach the zygomatic arch.^{5,6} The caudal aspect of the TMJ is covered by the rostradorsal aspect of the parotid salivary gland, which also covers the superficial temporal artery, vein, and auriculopalpebral nerve.^{5,6}

Function

The primary function of the TMJ is to permit mastication. Unlike ruminants, which regurgitate their food, horses only have one cycle to masticate feed to a small particle size to allow efficient microbial digestion.¹⁰ Unlike carnivores, whose power stroke of mastication is primarily vertical, the equine masticatory cycle has three distinct phases that allow for effective grinding of feed: the opening, vertical stroke; the closing, vertical stroke; and the powerful, lateral power stroke, during which feed is ground.^{4,11–13} The configuration of the TMJ allows this lateral movement of the mandible, which is initiated by the pterygoideus muscle. The side-to-side movement of the mandible within the joint capsule is coupled with rostrocaudal movement, with one side of the mandible gliding rostrally, and the other side of the mandible gliding caudally.^{4,11–13} Dental occlusion¹³ and type of feed¹² have been found to have a significant influence on motion of the TMJ.

Diseases of the TMJ

The equine TMJ is afflicted by the same diseases that afflict other synovial joints and include acute septic arthritis,^{14–17} (sub)luxation,^{18,19} osteoarthritis,^{16,20} and congenital dysplasia (H. Gerhards, personal communication). Tearing of the intra-articular disc has been reported.¹⁶

Septic arthritis

Septic arthritis of the TMJ has occurred in association with open fractures and wounds that communicate with the joint or from spread of infection from surrounding tissue (e.g.,

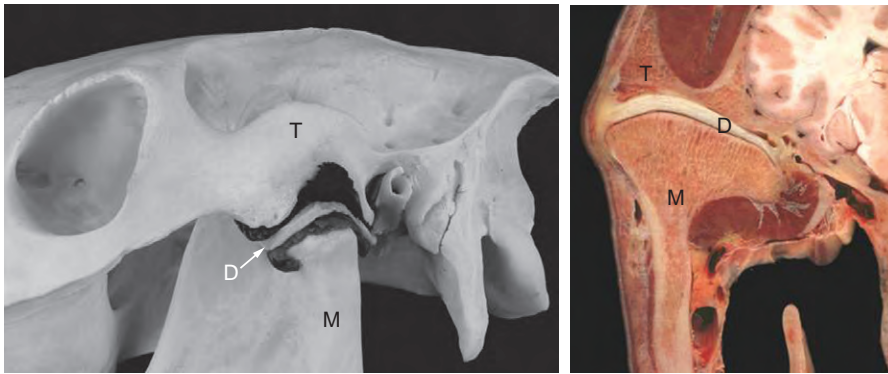


Fig. 23.1 Anatomy of the temporomandibular joint (TMJ). The image on the left shows the skeletal components of the TMJ and a corrosion cast of the dorsal and ventral compartments with the fibrocartilaginous disk wedged between them. The right image shows a transverse section through the TMJ in a frozen cadaver specimen. T, temporal bone; M, mandibular bone; D, intra-articular disc.

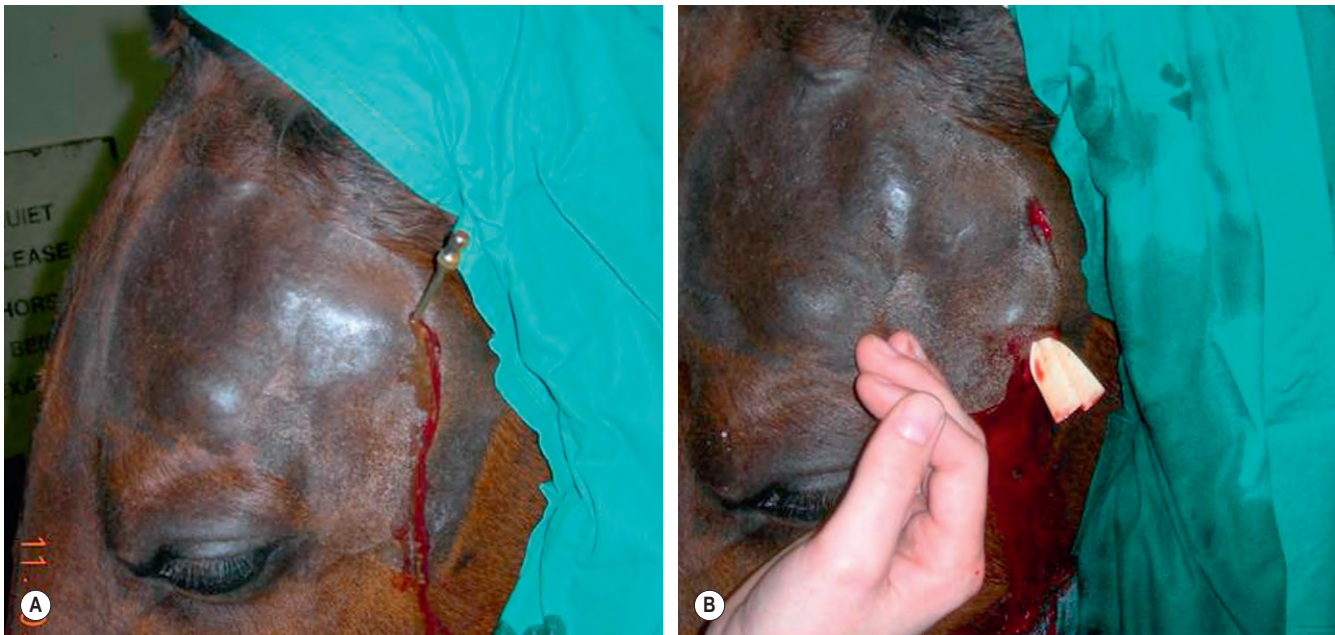


Fig. 23.2 A horse affected with infectious osteoarthritis of the TMJ. The horse had a marked swelling of its left TMJ, which when palpated caused the horse to show signs of pain. A test cannula was positioned in the caudal recess of the discotemporal compartment of the TMJ for lavage of this compartment performed with the horse sedated. The picture on the right shows the placement of a Penrose drain into a distal portal.

from tissue infected with *Streptococcus equi* var. *equi* in horses suffering from strangles).¹⁵ In many cases, an underlying cause cannot be established, and the horses are presented because of a masticatory problem, swelling of the TMJ, or a discharging tract.^{14,17,21,22}

Horses suffering from sepsis of the TMJ are presented for examination because they have a swelling, often painful, over the affected TMJ and are dull and have difficulty eating (Fig. 23.2).^{14,17,21,22} In some cases, a fistulous tract may be evident.¹⁷ Typically, the demeanor and masticatory function of horses suffering from sepsis of the TMJ improves while the horse is receiving antimicrobial therapy, but dullness and difficulty eating recur when antimicrobial therapy ceases.

Unless sepsis is accompanied by fracture, luxation, or subluxation, radiographic examination of the TMJ is often inconclusive, and another imaging modality, such as ultrasonography, scintigraphy, or computed tomography, is needed to diagnose septic osteoarthritis.^{17,23} Arthrocentesis of a septic TMJ typically yields abnormal-appearing synovial fluid that contains an increased nucleated cell count.¹⁴

Streptococcus zooepidemicus is often cultured from an infected TMJ.^{14,17,22}

(Sub)luxation

The TMJ can become luxated or subluxated, with or without fracture of the mandible.^{18,19,24} Affected horses usually have evidence of trauma to the head. Clinical signs depend on the degree of luxation and may include acute swelling of the region of the TMJ, rostral displacement of the mandible, decreased lateral range of movement of the mandible, an inability to open the mouth, difficult mastication, and rupture of an eye. Horses with a luxated or subluxated TMJ may develop osteoarthritis regardless of whether or not they are treated.

Osteoarthritis

Clinical signs of disease displayed by horses with osteoarthritis of the TMJ are often similar to signs of disease

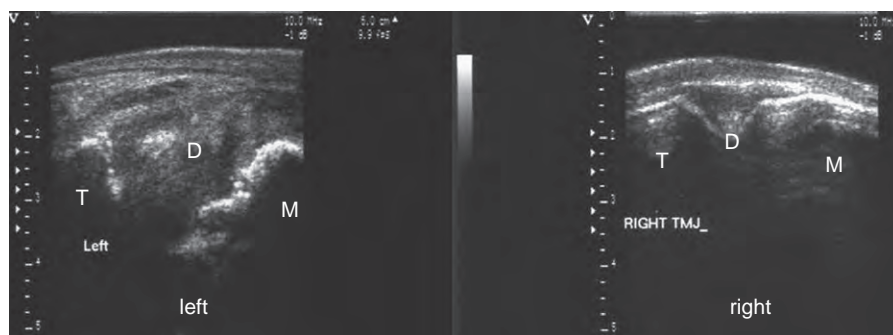


Fig. 23.3 Ultrasonograms of a horse with osteoarthritis of the left TMJ. The right TMJ is normal, whereas the left has extensive formation of new bone at the surface of the joint, joint effusion, and thickening of the joint capsule. T, temporal bone; M, mandibular bone; D, intra-articular disc.

displayed by horses with septic arthritis of that joint, though the clinical signs displayed by horses with osteoarthritis are often less severe and their onset is more insidious.^{16,23,24} Affected horses typically show a decreased range of mandibular motion and masticate preferentially on the non-affected side of the mandible. Joint distension and bony swelling are usually present over the affected TMJ, and if the disease is chronic, atrophy of the masseter muscles may be evident.

A strong association between disorders of the TMJ and dental malocclusion has been demonstrated in human beings,²⁵ and this same association is noted in horses chronically affected with osteoarthritis of the TMJ. The incisor arcades of horses chronically affected may become slanted, and the molar arcade on the affected side of the head may wear at an extremely steep angle, causing shear mouth. Determining whether disease of the TMJ is a result or a cause of abnormality of the incisor arcades may be difficult. Osteoarthritis has occurred secondary to rupture of the articular disc, but most commonly, no underlying cause is identified.¹⁶

Identifying arthritis of the TMJ radiographically is often difficult, and other methods of imaging the joint, such as ultrasonography or scintigraphy, may be more useful. Ultrasonographic features of an arthritic TMJ include an irregular contour to both the temporal and mandibular components of the joint and an abnormally large volume of synovial fluid (Fig. 23.3). Typical scintigraphic findings include a mild to moderate increase in radiopharmaceutical uptake over the affected joint compared to the unaffected, contralateral TMJ. Arthrocentesis of the arthritic TMJ yields synovial fluid that is less viscous than normal and that has a normal nucleated cell count and a normal or mildly elevated concentration of protein. Proliferative new bone formation and cartilage loss are features observed during arthroscopic examination of the joint (Fig. 23.4).

Diagnosis of disease of the TMJ

Clinical examination

Clinical signs associated with disorders of the TMJ range from very specific (e.g., swelling over the joint, a discharging sinus tract from the joint, or displacement of the mandible) to non-specific (e.g., headshaking, head-tilt, reluctance to be ridden, and weight loss). Clinical examination should start with observing the horse for signs of disease reported by the owner. If signs of disease are vague, examination of multiple



Fig. 23.4 Post-mortem specimen of a donkey with osteoarthritis of the left TMJ. Note the extensive new bone formation on the medial surface of the mandibular condyle (arrows).

body systems may be necessary before the TMJ is incriminated as the source of these vague signs.

Examination of a horse suspected of having a disorder of the TMJ should include careful inspection of the horse while it masticates rough feed, and special attention should be paid to the symmetry of the side-to-side movement of the jaw. The TMJs work as a functional unit, and in normal horses, the grinding motion is symmetrical. Pain or mechanical impairment at the TMJ results in a reduced range of motion of the mandible on the affected side. If disease of a TMJ is suspected, the dental arcades should be examined because disease of one or both TMJs commonly results in malocclusion.^{20,26}

Systematic palpation of the TMJ region may cause the horse to demonstrate signs of pain or may reveal a swelling of soft tissue or bony consistency (Fig. 23.2). The TMJ is located by following the mandibular ramus dorsally. The palpable depression representing the neck of the mandibular condyle should not be mistaken for the TMJ. The joint space lies dorsal to the mandibular condyle, the lateral aspect of which can be palpated as a smooth projection lying halfway between the lateral canthus of the eye and the base of the ipsilateral ear. Making the horse move its mandible while palpating this region helps to locate the mandibular condyle. In our experience, findings during palpation vary widely between horses, depending on the breed and condition of the horse. In some horses, the pouches of the joint capsule, especially the caudal pouch of the discotemporal compartment, are very prominent, but the pouches of the disco-mandibular compartment cannot be palpated. The lateral aspect of the mandibular condyle of some horses is very

prominent, but that of others is very difficult to palpate. Even though the palpable portion of the TMJs varies in morphology, the left and right regions of the TMJ should be symmetrical. To better appreciate function of the joint, the joint can be palpated while the horse chews.

Intra-articular anesthesia and arthrocentesis

Because the TMJ is separated completely into two compartments by the articular disc, each compartment probably must be injected separately to completely desensitize the entire joint. No studies have examined the likelihood of local anesthetic solution diffusing in a high enough concentration from one compartment to the other to result in desensitization of both compartments. Centesis of the TMJ performed directly over the joint is difficult because articular cartilage and the meniscus primarily occupy this space, and consequently centesis is most reliably performed over the caudal pouch of the dorsal compartment. The technique of arthrocentesis was thoroughly described by Rosenstein et al (2001)⁹ and Weller et al (2002).²⁷ Using the approach to the caudal pouch of the dorsal compartment (i.e., the discotemporal compartment) described by Rosenstein et al (2001),⁹ the mandibular condyle is identified as a smooth protrusion approximately midway between the lateral canthus of the eye and the base of the ear. The zygomatic process of the temporal bone is palpated 1–2 cm dorsal to the condyle, and a line is imagined between these structures. The site of centesis is a depression midway between these structures and $\frac{1}{2}$ to 1 cm caudal to the imagined line. The discotemporal compartment is desensitized with 2–2.5 ml of local anesthetic solution (Fig. 23.2). The ventral compartment (i.e., the discomandibular compartment) is injected with 1–1.5 ml of local anesthetic solution by walking the needle off the rostral aspect of the mandibular condyle.

Although the capsule of both pouches is relatively superficial, care must be taken not to inject the anesthetic solution outside the joint capsule where it may anesthetize branches of one of the cranial nerves in this area. In some cases, performing the procedure under ultrasonographic control may be beneficial. In our experience, the clinical signs of disease displayed by the majority of horses with TMJ disorders, such as decreased range of mandibular motion, resolve while the TMJ is temporarily desensitized. If the joint has advanced osteoarthritis, mobility of the mandible may be mechanically impaired.

Radiography

Radiographic evaluation of the TMJ is challenging, largely because the complexity of this area results in numerous superimpositions over the joint.^{28–30} To alleviate the problem of superimposition, the TMJ can be examined radiographically using special projections. To obtain the radiographic projection described by Pommer (1948),³¹ the X-ray cassette is placed 120 cm lateral to the TMJ of interest, and the X-ray beam is directed toward the contralateral TMJ (Fig. 23.5). Using this technique, the TMJ of interest is magnified to such a degree that evaluation of that joint is enhanced. This technique exposes the horse to a high concentration of radiation and consequently, the eye of the horse nearest the X-ray tube should be protected with a lead shield.

Recently, two oblique projections have been described that allow evaluation of the TMJ and surrounding osseous structures without superimposition of contralateral structures.^{32,33} For one of these projections, the X-ray cassette is placed above the horse's poll in a horizontal position, with the horse's head fully extended, and the X-ray beam centered on the ipsilateral TMJ and directed caudally at a 35° angle to the long axis of the head and 50° dorsally.³² For the other projection, the horse's head is held in a neutral position, and the cassette is placed parallel to the sagittal plane next to the TMJ of interest. The X-ray beam is directed caudodorsally to rostroventrally, from the contralateral side, to the TMJ of interest (Fig. 23.6).³³ If the TMJ of interest is the left TMJ, this projection is termed a right, caudodorsal-to-left, rostroventral oblique (Rt15Cd70D-LeRVO). Both projections allow evaluation of subchondral bone, a feature not allowed by other radiographic projections.

A luxation or subluxation of the TMJ, with or without a fracture(s), is usually easily identified on radiographs as an incongruence of the bony surfaces of the TMJ and an incongruence of the occlusal surfaces of the incisors and cheek teeth. Osteoarthritic changes are much more difficult to appreciate radiographically. If osteoarthritis is severe, an irregular outline of the bones forming the joint, as well as periarticular new bone formation and changes in the width of the joint, can be appreciated. In our experience, the majority of old horses have some degree of osteophyte formation on the caudal aspect of the mandibular condyle (Fig. 23.5) yet show no clinical signs of disease of the TMJ, indicating that osteophytes in this area may not be clinically significant. Mild changes of osteoarthritis are difficult to appreciate during radiographic examination of the TMJ.

Scintigraphy

Scintigraphy is an imaging modality that portrays function rather than morphological changes. It is the most sensitive of all imaging modalities for a variety of diseases, including dental disorders.²⁷ To examine the TMJs of a horse scintigraphically, the horse is injected intravenously with 5 MBq/kg ^{99m}Tc-phosphonate. This dosage equates to half the dose usually used for imaging other parts of the horse, but in our experience, this reduced dose is sufficient to evaluate the head. We have found that the vascular and soft tissue phases are not useful for this area, and therefore we perform only a bone phase, usually about three hours after injection. Left and right lateral projections and a dorsal projection, each centered over the TMJ of interest, are acquired. Both TMJs should be adjacent to the camera during acquisition of images to avoid differences in radiopharmaceutical uptake caused by distance attenuation of the gamma radiation.

The resulting images should be evaluated visually, as well as quantitatively, by defining regions of interest (ROI) over the TMJs. On the dorsal projection the ROIs are compared directly, whereas on the lateral projections reference ROIs are defined over the ramus of the mandible (Fig. 23.7). The ratio between the ROI over the TMJ and the reference ROI is calculated and compared between sides. Radiopharmaceutical uptake by structures of the head, including the TMJs, varies with the age of the horse. The TMJs of young horses take up considerably more of the radiopharmaceutical drug than does the relatively inactive rest of the mandible, whereas

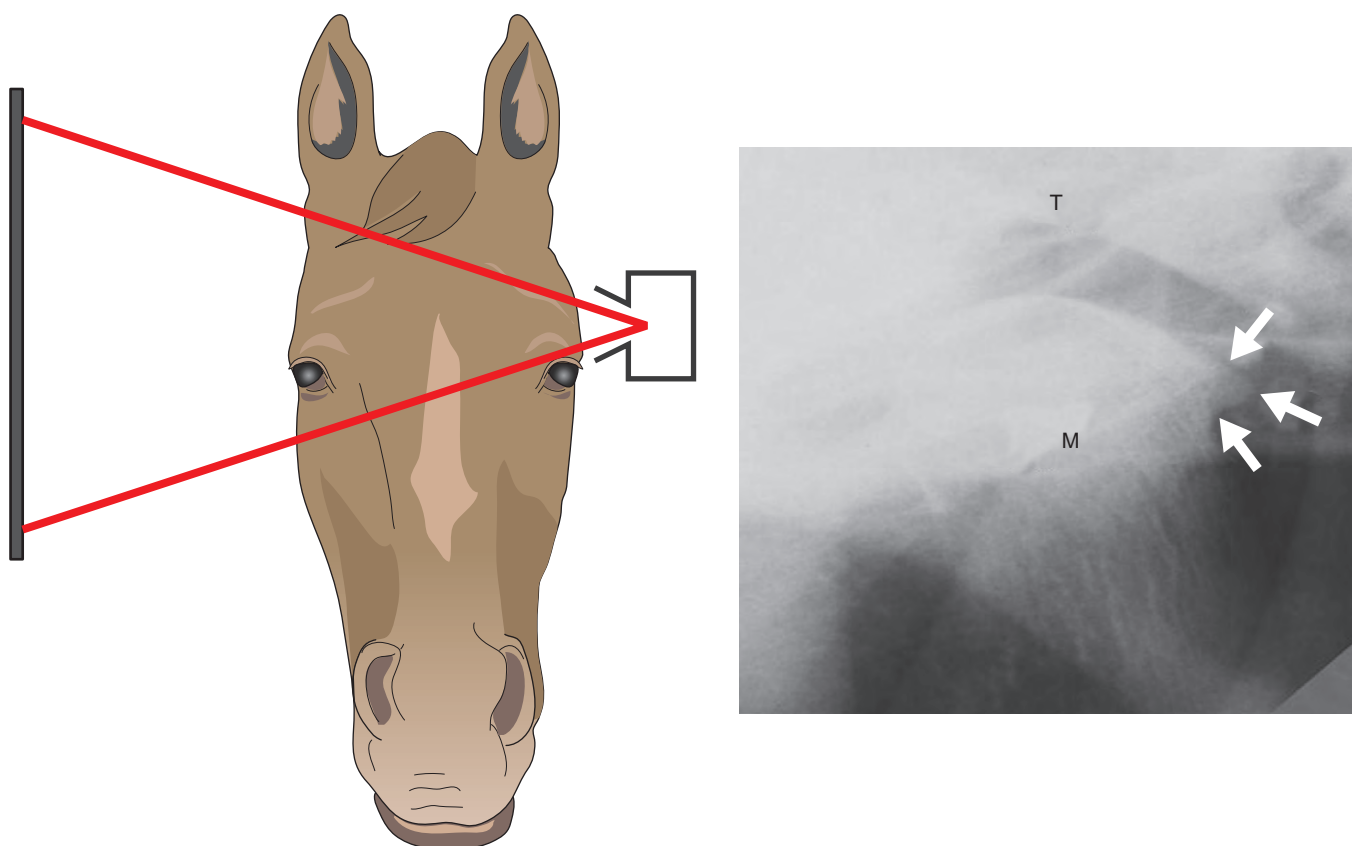


Fig. 23.5 Radiographic projection of the TMJ. The image shows a projection of the left TMJ of a 23-year-old horse. This projection, described by Pommer (1948),³¹ allows evaluation of the TMJ of interest by magnifying the superimposed contralateral TMJ. Note the osteophyte on the caudal aspect of the mandibular condyle (arrows), which is commonly seen in old horses.

the TMJs of old horses often cannot be differentiated from the surrounding tissues (Fig. 23.8). In our experience, a difference in radiopharmaceutical uptake by a TMJ of more than 25% is indicative of disease of that joint.

The left and right TMJs are structurally linked and, therefore, function as a unit. Disorders of the TMJ of human beings resulting from malocclusion are often bilateral, and we believe disorders of the TMJ of horses are likewise bilateral. Marked radiopharmaceutical uptake over both TMJs in an old horse may be suggestive of disease of both TMJs.

Ultrasonography

Ultrasonographic examination of the TMJs is easily performed with the horse standing and is usually well tolerated by the horse.^{7,34} To obtain optimal quality of the image, hair over the TMJ to be examined should be clipped, but the procedure can sometimes be performed adequately without clipping the hair. The area is cleansed and covered with a coupling gel. Both TMJs should be examined for comparison. A 7.5 MHz (or higher) linear array transducer provides sufficient depth to image the TMJ, while still providing excellent resolution of the images.

The transducer should be positioned perpendicular to the joint space to acquire transverse images of the joint, and so, to keep the transducer perpendicular to the curved outline of the lateral aspect of the joint, the transducer must be

rotated as the joint is examined. To examine the TMJ ultrasonographically, we follow the mandible dorsally with the transducer orientated approximately parallel to the dorsal outline of the horse's nose until the caudal aspect of the joint can be imaged. To image the medial aspect of the joint, the transducer is rotated dorsorostrally by 45°. To image the rostral part of the joint, the transducer is rotated another 30° in the same direction while applying slight rostroventral translation. A stand-off is usually not required, but may be useful if the horse is thin.

The ultrasonographic examination allows evaluation of the bony surfaces of the joint, the fibrocartilagenous disc, and the joint capsule, and quantification of the amount of synovial fluid within the joint. The surface of the bones should appear as smooth, hyperechogenic lines. The disc appears as a homogenous wedge, the base of which is located laterally and the apex of which points medially, between the surface of the zygomatic process of the temporal bone and the surface of the mandibular condyle and is similar in echogenicity to the menisci in the stifle. The caudal recess of the discotemporal compartment of the TMJ is filled with synovial villi and is difficult to distinguish ultrasonographically from the disc. The joint capsule is visible as an interface between the disc and the parotid salivary gland, which overlies it on the caudal part of the joint, or subcutaneous tissue, which overlies it on the rostral part of the joint. No synovial fluid, or only a very minimal amount, is visible if the TMJ is

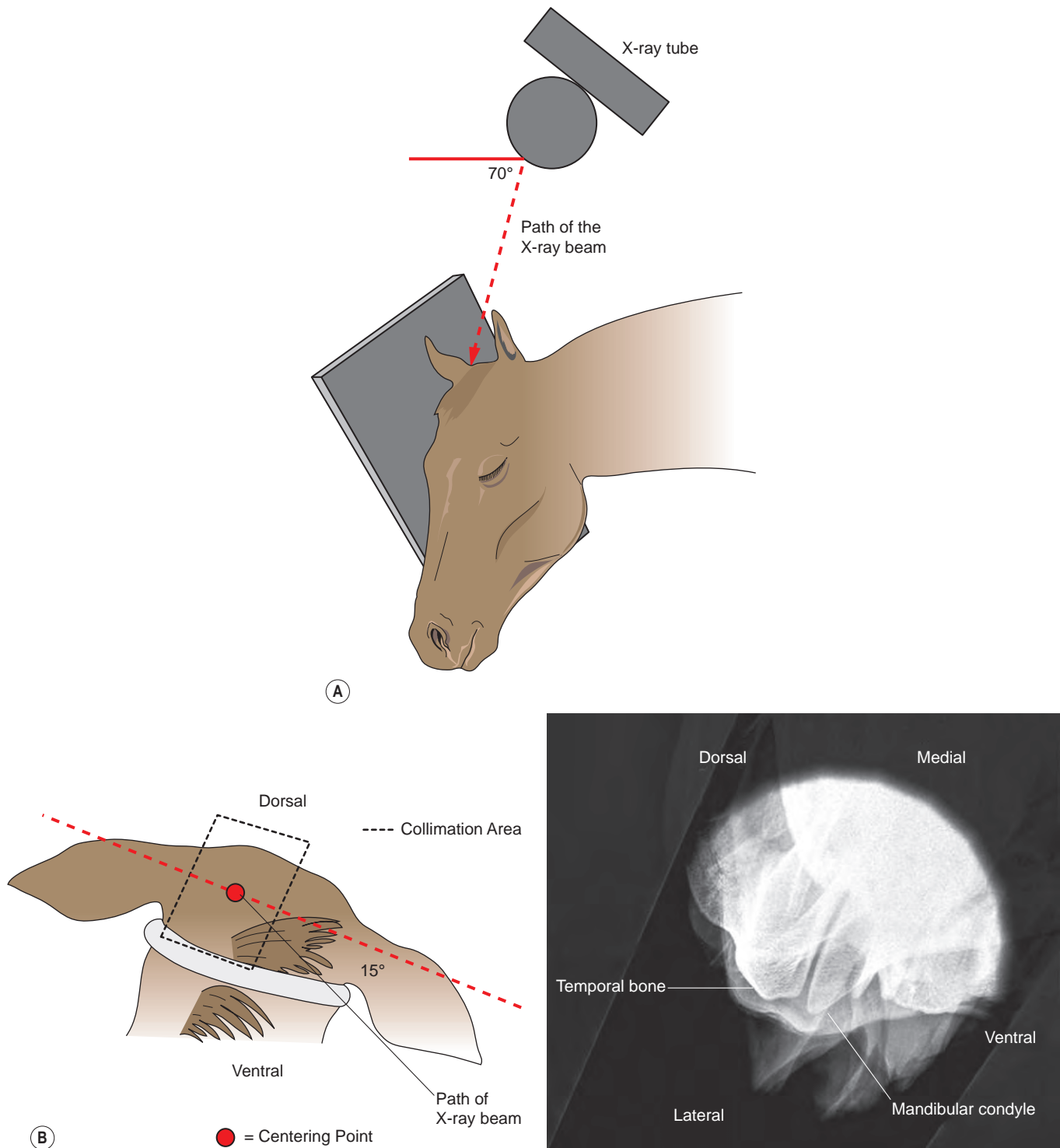


Fig. 23.6 Tangential projection of the equine TMJ described by Townsend (2009).³³ (A) This schematic drawing illustrates the X-ray beam angle at 70° to the dorsal plane and cassette; (B) Dorsal view of the radiographic projection showing the beam angle at 15° to the centering point and the collimation area. The radiographic image on the right is the result of this projection.

normal. Changes in the TMJ seen ultrasonographically that are pathognomonic for disease of the joint include irregular outline of the bony surfaces, increased amount of synovial fluid, hyperechogenicity of the synovial fluid, disruption of the homogenous appearance of the disc, or thickening of the joint capsule (Fig. 23.3).

Computed tomography

Computed tomography (CT) is the method of imaging of choice for diagnosing disorders of the TMJ of human beings and small animals.³⁵ It allows the medial components of the joint to be evaluated without superimposition of other

structures. Computed tomographic anatomy of the normal TMJ of horses has been described,³⁶ and CT has been used to diagnose septic arthritis of the TMJ of a horse.¹⁷ Until recently, to image the head of a horse using CT, the horse had to be anesthetized, which increased the costs and risks of the procedure. Now, some equine referral centers can perform CT scans of the head with the horse sedated, which has led to a wider use of this modality for diagnosing disorders of the equine head.

Treatment

Horses with a disorder of the TMJ can be treated conservatively or surgically, according to the type of disorder.

Conservative treatment

Conservative treatments available for horses with a disorder of the TMJ are similar to those available for a horse with a disorder of any other similarly affected joint with similar likelihood of success. Intra-articular injection of a corticosteroid has been used successfully to treat horses with

non-septic osteoarthritis of the TMJ.¹⁶ We have observed good, long-term outcome after administering methylprednisolone acetate into the TMJ of horses affected with osteoarthritis of that joint. Those horses that did not respond to treatment had evidence of advanced osteoarthritis seen during post-mortem examination (Fig. 23.4). We have had limited success in resolving clinical signs of osteoarthritis of the TMJ after administering a glycosaminoglycan and hyaluronic acid into the TMJ.

Dental malocclusion accompanies disease of the TMJ of human beings and likely also accompanies disease of the TMJ of horses. Determining whether disease of the TMJ is a result or a cause of abnormal malocclusion may be difficult. Horses affected with disease of a TMJ should be carefully examined for dental malocclusion, and any occlusal abnormalities, such as shear mouth and slant mouth, should be corrected.

Surgical treatment

There are few reports of surgical management of horses with disease of the TMJ. Rostral luxation of a TMJ of one horse was successfully corrected, with the horse anesthetized, by placing a metal mouth gag between the cheek teeth on the affected side and placing pressure on the rostral aspect of the mandible and on the rostral aspect of the maxillae to close the mouth.¹⁹ After recovering from anesthesia, the horse was able to masticate food, though the horse was permanently blind in the ipsilateral eye, probably from damage to the eye inflicted by the coronoid process of the mandible when it displaced rostrally.

Arthroscopic evaluation of osteoarthritic TMJs and arthroscopic lavage of septic TMJs have been described.^{8,14,16} Due to the bipartite nature of the TMJ, the discotemporal and discomandibular compartments of the TMJ must be evaluated through individual arthroscopic portals, but only the lateral aspect of the discotemporal joint can be evaluated fully because the curvature of the mandibular condyle renders the rest of the joint inaccessible.^{6,8} Authors of one report declared the discomandibular joint to be inaccessible because of the position of the transverse facial artery and vein;⁸ other authors reported it to be accessible, though difficult to evaluate due to obstruction of vision by synovial villi and poor maneuverability.⁶

To examine the TMJ joint arthroscopically, the horse is anesthetized and positioned in lateral recumbency with the

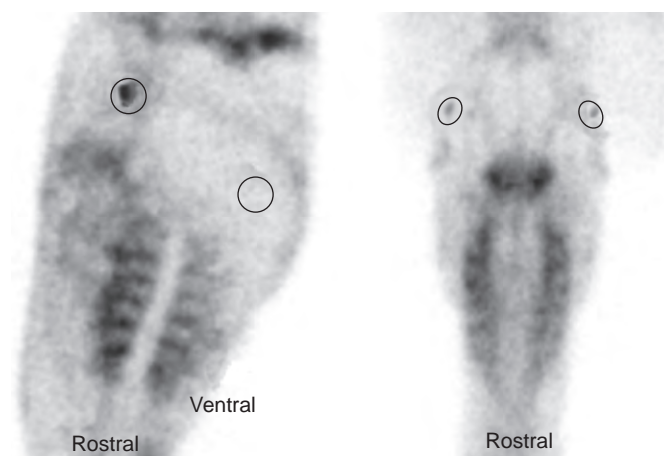


Fig. 23.7 Lateral (left image) and dorsal (right image) scintigrams of the TMJs of a horse, 3 hours after the horse was injected with TC99m-methylenediphosphonate. Regions of interest are drawn around the TMJs, and reference regions of interest (ROIs) are defined over the ramus of the mandible. The ratio between the ROI over the TMJ and the reference ROI is calculated and compared between sides.

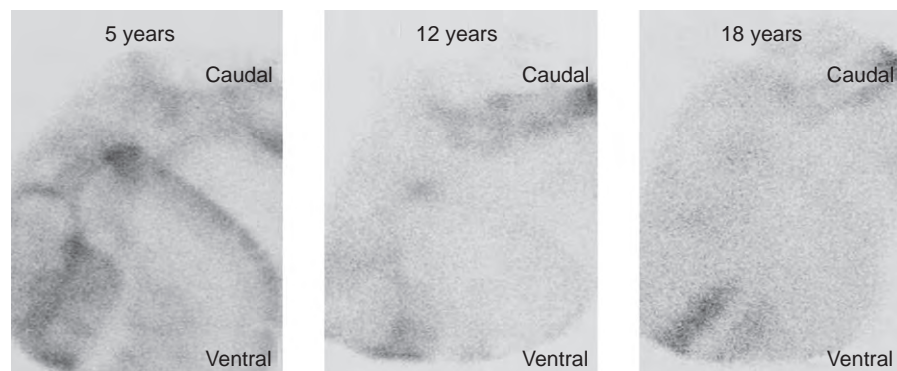


Fig. 23.8 Left lateral scintigrams of the TMJs of three horses of different ages, 3 hours after injection of TC99m-methylenediphosphonate. The uptake of the radiopharmaceutical drug decreases remarkably as horses age.

affected TMJ uppermost. The horse can be positioned in dorsal recumbency if both TMJs are to be arthroscopically examined. After preparing the region of the TMJ for aseptic surgery, the TMJ is distended with sterile, isotonic saline solution after inserting a needle into the compartment of the joint using a technique described above, with or without ultrasonographic guidance. The needle is left in place, and a longitudinal, 5 mm long, skin incision is made adjacent to it. An arthroscopic sleeve and blunt obturator are introduced into the joint, through the incision, in a rostromedial direction. The obturator is replaced with a 4-mm diameter, 30°, forward arthroscope, and the joint is distended, through the arthroscope, with sterile, isotonic saline solution. A needle can be placed into the joint further rostrally to allow egress of fluid, which is important for improving visualization if the original penetration by the obturator caused intra-articular hemorrhage, and for providing continuous lavage of the joint.

A septic discotemporal compartment can be lavaged with the horse standing and sedated if financial constraints imposed by the owner make performing the procedure with the horse anesthetized unfeasible. The region of the affected TMJ is prepared for aseptic surgery, and local anesthetic solution is infiltrated subcutaneously at the site for arthrocentesis of the caudal recess of the discotemporal compartment described above. This is a palpable depression just dorsal and caudal to the mandibular condyle, which lies halfway between the lateral canthus of the eye and the base of the ipsilateral ear. A needle is placed into the discotemporal compartment, and the joint is distended with 10–25 ml of

sterile, isotonic saline solution. A 5-mm long, longitudinal incision is made in the skin at this site with a no. 15 blade. A 10-cm long, blunt, teat cannula with obturator is placed through this incision and directed rostromedially into the joint (Fig. 23.2). Egress of fluid confirms that the cannula has been placed into the joint. A 16-gauge, 2.54-cm (1-inch) needle is placed in the most dependent part of the distended TMJ, and a 5-mm long, longitudinal skin incision made adjacent to it. A second teat cannula is placed through this incision into the compartment to allow egress of fluid introduced into the joint through the other teat cannula. After the joint has been lavaged, a Penrose drain can be placed into the TMJ through the ventral skin incision (Fig. 23.2) and maintained, with a suture, for several days before it is removed.

Unilateral, mandibular condylectomy and meniscectomy has been reported to be a successful treatment for horses with severe septic or non-septic osteoarthritis of the TMJ.^{22,24,37} When mandibular condylectomy was performed bilaterally, more severe and longer-lasting abnormalities of mastication were observed.³⁷ Deviation of the mandible toward the non-treated side was reported to occur after unilateral condylectomy and meniscectomy.³⁷ Deviation was thought to be caused by a temporary lack of stability of the joint and atrophy of the masseter muscle on the treated side. A horse in a more recent report, however, did not experience deviation of the mandible after unilateral condylectomy and meniscectomy and had immediate improvement in its ability to open its mouth and to masticate.²²

References

1. Rugh JD, Solberg WK. Oral health status in the United States: temporomandibular joint disorders. *Journal of Dental Education* 1985; 49: 398–405
2. Barone R. *Articulation temporo-mandibulaire*. Vigot, Paris, 1989
3. Hillman DJ, ed. *Scisson and Grossman's Anatomy of the domestic species*. W.B. Saunders, Philadelphia, 1975
4. Baker GJ. Equine temporomandibular joints (tmj): morphology, function and clinical disease. *Proceedings AAEP* 2002; 48: 442–447
5. Rodriguez MJ, Agut A, Gil F, Latorre R. Anatomy of the equine temporomandibular joint: study by gross dissection, vascular injection and section. *Equine Vet J* 2006; 38(2): 143–147
6. Weller R, Maierl J, Bowen IM, et al. The arthroscopic approach and intra-articular anatomy of the equine temporomandibular joint. *Equine Vet J* 2002; 34(4): 421–424
7. Weller R, Taylor S, Maierl J, et al. Ultrasonographic anatomy of the equine temporomandibular joint. *Equine Vet J* 1999; 31(6): 529–532
8. May KA, Moll HD, Howard RD, et al. Arthroscopic anatomy of the equine temporomandibular joint. *Vet Surg* 2001; 30(6): 564–571
9. Rosenstein DS, Bullock ME, Ocello PJ, Clayton HM. Arthrocentesis of the temporomandibular joint in adult horses. *Am J Vet Res* 2001; 62(5): 729–733
10. Dixon PM. Dental anatomy. In: Baker GE, Easley J, eds. *Equine dentistry*, 2nd edn. Elsevier, Edinburgh 2005: 25–48
11. Bonin SJ, Clayton HM, Lanovaz JL, Johnson TJ. Kinematics of the equine temporomandibular joint. *Am J Vet Res* 2006; 67(3): 423–428
12. Bonin SJ, Clayton HM, Lanovaz JL, Johnston T. Comparison of mandibular motion in horses chewing hay and pellets. *Equine Veterinary Journal* 2007; 39(3): 258–262
13. Simhofer H, Anen C, Niederl M, et al. Comparison of the Masticatory Cycles of Horses Before and after Dental Treatment Using Kinematic Analysis. In: 6th international Conference on Equine Locomotion. Cabourg, France, 2008 p. 19
14. Carmalt JL, Wilson DG. Arthroscopic treatment of temporomandibular joint sepsis in a horse. *Vet Surg* 2005; 34(1): 55–58
15. Silbersiepe E. Die Entzündung des Kiefergelenkes. In: Silbersiepe E, Berge E, Müller H, eds. *Lehrbuch der Speziellen Chirurgie für Tierärzte und Studierende*. Ferdinand Enke Verlag, Stuttgart, 1986, pp 119–120
16. Stadtbäumer G, Boening KJ. Diagnostische und arthroskopische Verfahren am Kiefergelenk des Pferdes. *Tierärztl Prax* 2002; 30: 99–106
17. Warmerdam EP, Klein WR, van Herpen BP. Infectious temporomandibular joint disease in the horse: computed tomographic diagnosis and treatment of two cases. *Vet Rec* 1997; 141(7): 172–174
18. Hardy J, Shiroma JT. What is your diagnosis? Rostral luxation of the right temporomandibular joint. *J Am Vet Med Assoc* 1991; 198: 1663–1664
19. Hurtig MB, Barber SM, Farrow CS. Temporomandibular joint luxation in a horse. *J Am Vet Med Assoc* 1984; 185(1): 78–80
20. Grosse G. Die Veränderungen am Kiefergelenk des Pferdes in Verbindung mit Zahn- und Gebißanomalien, Veterinärmedizinische Dissertation. Justus Liebig Universität, Leipzig, 1938
21. Devine DV, Moll HD, Bahr RJ. Fracture, luxation, and chronic septic arthritis of the temporomandibular joint in a juvenile horse. *Journal of Veterinary Dentistry* 2005; 22(2): 96–99

22. Nagy AD, Simhofer H. Mandibular condylectomy and meniscectomy for the treatment of septic temporomandibular joint arthritis in a horse. *Vet Surg* 2006; 35(7): 663–668
23. Weller R, Cauvin ER, Bowen IM, May SA. Comparison of radiography, scintigraphy and ultrasonography in the diagnosis of a case of temporomandibular joint arthropathy in a horse. *Vet Rec* 1999; 144(14): 377–379
24. Patterson LJ, Shappell KK, Hurtig MB. Mandibular condylectomy in a horse. *J Am Vet Med Assoc* 1989; 195(1): 101–102
25. Payne M, Nakielny RA. Temporomandibular joint imaging. *Clin Radiol* 1996; 51(1): 1–10
26. May KJ. Incisor problems that may result in inflammation of the temporomandibular joint. *Pferdeheilkunde* 1996; 12: 716
27. Weller R, Livesey L, Maierl J, et al. Comparison of radiography and scintigraphy in the diagnosis of dental disorders in the horse. *Equine Vet J* 2002; 33(1): 49–58
28. Gibbs C, Lane JG. Radiographic examination of the facial, nasal and paranasal sinus regions of the horse. II. Radiological findings. *Equine Vet J* 1987; 19(5): 474–482
29. Park RD. Radiographic examination of the equine head. *Vet Clin North Am Equine Pract* 1993; 9(1): 49–74
30. Wyn-Jones G. Interpreting radiographs 6: Radiology of the equine head (Part 2). *Equine Vet J* 1985; 17(6): 417–425
31. Pommer A. Die röntgenologische Darstellung des Kiefergelenkes des Pferdes. *Wiener Tierärztliche Wochenschrift* 1994; 36: 230
32. Ramzan PH, Marr CM, Meehan J, Thompson A. Novel oblique radiographic projection of the temporomandibular articulation of horses. *Vet Rec* 2008; 162(22): 714–716
33. Townsend NB, Cotton JC, Barakzai SZ. A tangential radiographic projection for investigation of the equine temporomandibular joint. *Vet Surg* 2009; 38(5): 601–606
34. Rodriguez MJ, Soler M, Latorre R, et al. Ultrasonographic anatomy of the temporomandibular joint in healthy pure-bred Spanish horses. *Vet Radiol Ultrasound* 2007; 48(2): 149–154
35. Schwarz T, Weller R, Dickie AM, et al. Imaging of the canine and feline temporomandibular joint: a review. *Vet Radiol Ultrasound* 2002; 43(2): 85–97
36. Rodriguez MJ, Latorre R, Lopez-Albors O, et al. Computed tomographic anatomy of the temporomandibular joint in the young horse. *Equine Vet J* 2008; 40(6): 566–571
37. Barber SM, Doige CE, Humphreys SG. Mandibular condylectomy – Technique and results in normal horses. *Veterinary Surgery* 1985; 14(2): 79–86

Appendix

Equine dental equipment and instrument suppliers

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Equine dental terminology

- Ablation** – Taking away, wearing down, erosion of an area.
- Abrasion** – Mechanical wearing away of teeth by abnormal stresses.
- Abrasive points** – Burrs, rotary instruments that have an abrasive coating on the operative head.
- Abscess** – Collection of pus, generally as a result of an infection.
- Absorbent points** – Cones of porous paper used to dry the root canal after instrumentation.
- Acellular cementum** – Cementum that has no cells within it.
- Achondroplasia** – Developmental abnormality of cartilage. Failure of cartilage formation.
- Acid etching** – The microscopic roughening of enamel, dentinal or cemental surface with a dilute acid to increase its mechanically retentive property to restorative materials. Usually the procedure preferentially removes the enamel prism cores and leaves the prism peripheries intact.
- Acquired** – Pertaining to something obtained by itself, not inherited.
- Acrodont** – Tooth that is attached to the crest of the jaw through ankylosis and lacks root formation.
- Acrylic** – Basically methyl methacrylate resin, mixed from a powder (polymer) and liquid (monomer). Referring to synthetic compounds that contain acrylic acid, which is formed by the oxidization of acrolein.
- Adamantinoma** – Obsolete term for ameloblastoma.
- Aerobic bacteria** – Bacteria that thrive in the presence of oxygen.
- Ala (pl. Alae)** – Latin for wing, referring to the sides of the nostrils of the nose.
- Alginate** – Irreversible hydrocolloid impression material used in small animal dentistry, especially when partial – or full – mouth models are needed that require good, yet not excellent detail.
- Alignment** – Arrangement (e.g., of teeth) in a row.
- Allele** – An alternative form of a gene.
- Alveolar** – Of or pertaining to the sockets of the teeth.
- Alveolar bone** – Bone forming the sockets of the teeth.
- Alveolar crest** – Highest part of the alveolar bone closest to the occlusal surface of the tooth.
- Alveolar mucosa** – Mucous membrane covering the bone that contains the teeth.
- Alveolar nerve** – Branches of the mandibular nerve entering the mandibular foramen and innervating all mandibular teeth.
- Alveolar process** – The part of the maxilla or mandible that contains the alveoli of erupted teeth or the crypts of developing unerupted teeth.
- Alveolus** – The socket within the jaws in which the reserve crown and roots of a tooth lie.
- Amalgam** – An alloy or combination of finely powdered metals that are mixed, or triturated, with mercury to form a condensable mass.
- Amalgamation** – The process of combining an alloy with mercury (e.g., silver or copper alloy triturated with mercury makes up an amalgam).
- Amalgamator** – A mechanical device or a ground glass mortar and a glass pestle used to triturate an alloy.
- Amelo-(prefix)** – Indicating enamel or tissues of the epithelial odontogenic origin.
- Ameloblast** – Germ cell originating from epithelium from which the enamel is formed.
- Ameloblastic odontoma** – Dental tumor originating from the dental laminar epithelium.
- Ameloblastoma** – The most common tumor (enamel cell origin) of the dental laminar epithelium. It is slow-growing but often demonstrates a multiple cystic structure and can extend into bone.
- Amelodentinal junction** – Junction between enamel and dentin.
- Amelogenesis** – The process of enamel formation.
- Amylase** – Enzyme in saliva and pancreatic juice. Converts starch into simple sugars.
- Anachoresis** – Exposure to bacteria through a hematogenous or lymphatic route.
- Anaplastic sarcoma** – Undifferentiated tumor of mesenchymal origin.
- Anatomical crown** – That part of the tooth where enamel constitutes a portion of its external or internal structure.
- Anatomical root** – That part of the tooth where enamel does not constitute a portion of its external or internal structure and is covered with cementum.
- Anelodont teeth** – Teeth with a limited period of growth; the root canals progressively narrow and the apical foramina become constricted with age. Subdivided into hypsodont and brachyodont.
- Angle of the mandible** – Junction of the horizontal and vertical ramus of the mandible.
- Angular process** – Portion of the vertical ramus of the mandible.
- Anisognathism** – Condition of having unequal jaw widths in which the distance between the mandibular cheek teeth rows is smaller than the distance between the maxillary cheek teeth rows. It is seen in the equine, feline, canine, bovine, and other species.
- Ankylosis** – Fusion of a tooth with alveolar bone. Joining together of bone and bone, by direct union of the parts, resulting in rigidity.
- Anodontia** – Condition in which most or all the teeth are congenitally absent, usually indicating a failure of tooth development.
- Anomaly** – A difference or deviation from that which is ordinary or normal.
- Anorexia** – Loss of appetite.
- Anterior (Rostral)** – Situated in or toward the front. This term is commonly used to denote the incisor and canine teeth or the area toward the front of the mouth.
- Anterior teeth** – Collective term for the incisors and canines.
- Antral** – Relating to an antrum.
- Antrum** – An air-filled natural cavity, usually in bone. Also called a sinus (e.g., maxillary antrum=maxillary sinus).

- Apexification** – Maturation of root ends.
- Apical** – Relating to the apex of a tooth, i.e., the root area of a mature tooth (or similar area of an immature tooth before root formation).
- Apical foramen, foramina (pl)** – Entrance(s) to the pulp cavities of a tooth (where the blood vessels, nerves, and lymphatics enter pulp).
- Apicoectomy** – Endodontic treatment that involves amputation of the root tip.
- Approximal, see Proximal** – Interproximal. Collective term that refers to surfaces of teeth that face adjoining teeth of the same dental arch or row.
- Alveolar hypsodont** – Dentition without true roots (sometimes referred to as open-rooted or elodont) that produces additional crown throughout life. As the tooth is worn down, new crown emerges from the continually growing tooth, as in lagomorphs and the incisors of rodents.
- Arcades** – Refers to the arches of teeth in some brachyodont species. In horses the straight rows of cheek teeth are separated from the incisors by the physiological diastema ('bars of mouth') so all of the teeth do not form an arch.
- Articular disc** – Fibrous disc, e.g., between the mandibular condyle and the zygomatic process of the temporal bone.
- Articular process** – Portion of the vertical ramus of the mandible that is part of the temporomandibular joint.
- Attrition** – Process of normal wear on the crown due to prehension and mastication.
- Auto-immune disease** – Immune-mediated inflammatory reaction to the host's own tissues.
- Avulsion** – Tearing away of a part, such as a tooth.
- Axial** – Pertaining to the longitudinal (long) axis of a structure.
- Bacterial plaque** – Dental plaque. Soft mass of microorganisms, cellular material and food debris that adheres to the surfaces of teeth and/or gingiva.
- Basal cell carcinoma** – Tumor originating from basal cell layer of epidermis.
- Beak** – Colloquial term for a dental overgrowth resembling the beak of a bird.
- Bell stage** – Third embryonic stage of enamel organ formation in which the crown form is established.
- Benign** – Non-malignant. Such lesions do not destroy the tissue from which they originate or spread to other parts of the body (metastasize).
- Bifurcation** – Division into two parts or branches, e.g., two roots of a tooth.
- Bisecting angle** – Technique of taking radiographs to minimize linear distortion by aiming the beam perpendicular to the line that bisects the angle formed by the long axis of the tooth and the film.
- Bishoping** – Tampering with the dental appearance of an animal, normally a horse, to make it look younger for fraudulent reasons by burning or drilling and staining an artificial concavity in the dentin of the incisors in an attempt to mimic the infundibulum of a younger animal.
- Bit** – Mechanical device held in the mouth and attached to the reins.
- Biting force** – The occlusal pressure (N/cm²) exerted by teeth when engaged by the muscles of mastication.
- Blast histology** – Embryonic cell or formative layer.
- Blind wolf tooth** – Colloquial term. Unerupted wolf tooth.
- Body of the mandible** – Horizontal portion of the mandible, excluding the alveolar processes.
- Bolus of food** – A ball of food that has been chewed and mixed with saliva and is ready to be swallowed.
- Bone** – Hard connective tissue that forms the skeleton of the body.
- Brachy- (prefix)** – Indicating something short.
- Brachycephaly** – Condition in which individuals have short, (usually broad) facial profiles.
- Brachygnathic** – Having an abnormally short mandible.
- Brachyodont** – Teeth with a short crown: root ratio (e.g., primates, dogs, cats, and carnivores in general).
- Brachygnathism, see Brachygnathic** – A congenital deformity in which the upper incisors overlap the lower incisors due to shortness of the mandible – however equine overjet and overbite may actually be due to elongation of the maxilla.
- Branchial arches I and II** – Developmental sections of the facial region.
- Bruxism** – Abnormal grinding of the teeth.
- Bucca** – Latin for 'cheek.'
- Buccal** – Pertaining to or directed toward the cheek (outside/lateral aspect of mouth).
- Bucco- (prefix)** – Signifying buccal, cheek.
- Buccostomy** – The formation of a surgical opening (fistula) through the side of the face that is later kept patent.
- Buccotomy** – Surgical incision made through the side of the face, usually performed in herbivores, to accomplish an intra-oral procedure that is inaccessible through an oral approach.
- Bud stage** – First stage of development of the enamel organ that develops from the dental lamina.
- Bullous pemphigoid** – Autoimmune disease frequently causing lesions at the oral mucocutaneous junction.
- Bundle bone** – Extra thickness of bone added to the cribriform plate of alveolar bone.
- Burrs (Burs)** – Rotary instruments with cutting blades or abrasive surfaces as an active part of the operative head.
- Cachexia** – Condition of weakness of the body and weight loss that results from a debilitating chronic disease.
- Calcification** – Process by which organic tissue becomes hardened by a deposit of calcium salts within its substance. Literally, the term denotes the deposition of any mineral salts that contribute toward hardening and maturation of tissue.
- Calculus** – Mineralized dental plaque that adheres to tooth surfaces and prosthetic dental materials.
- Campylorhinus lateralis (wry nose)** – Twisted premaxilla, nasal bones and nasal septum. Developmental abnormality.
- Canal** – Long tubular opening, e.g., through a bone or tooth root.
- Cancellous bone** – Less dense bone situated between surrounding denser cortical bone plates.
- Canine teeth** – The teeth found between the incisors and cheek teeth usually in male horses; the fighting teeth of a horse (Triadan 104, 204, 304, 404).
- Cap** – Colloquial term for the remnant of a deciduous cheek tooth that covers an erupting permanent cheek tooth (premolars only) and is later shed.
- Cap stage** – Second stage of enamel organ development.
- Capsule (joint)** – Fibrous band of tissue surrounding a joint and limiting its motion.
- Carbide** – Hard compound of carbon and another element such as tungsten used for making blades that can be used for grinding and floating equine teeth.
- Caries** – Demineralization of calcified dental tissues and destruction of their organic parts through the acid produced by microorganisms.
- Cariogenic acid** – Acid produced by cariogenic bacteria.
- Caudal** – Relating to the posterior aspect of a structure.
- Caudal infraorbital block** – Intraoral regional anesthetic nerve block achieved by injecting the infraorbital nerve at the caudal aspect of the infraorbital canal.
- Cellular cementum** – Cementum that has cells (cementocytes) trapped in it.

- Cellulitis** – Diffuse inflammation, often purulent, of the soft tissues.
- Cement** – Dental cement is a material used to apply orthodontic brackets, appliances, crowns, or other prosthodontic devices. A plastic material that is used to affix dental restorations. A type of filling material.
- Cementoblasts** – Cells that form cementum.
- Cementoclasts** – Cells that resorb cementum.
- Cementocytes** – Cementoblasts that have become entrapped within cementum.
- Cementodentinal junction (CDJ)** – Junction where the cementum and dentin contact.
- Cementoenamel junction (CEJ)** – Junction of enamel and cementum.
- Cementogenesis** – Process of cement formation.
- Cementoid** – Term meaning cementum-like.
- Cementoma** – Benign proliferation of the connective tissue that produces cementum or cementum-like tissue.
- Cement, cementum** – A bone-like, calcified component of teeth, includes peripheral cementum which composes a significant portion of the equine clinical crown and infundibular cementum.
- Cemental hypoplasia** – A developmental disorder commonly seen in maxillary cheek teeth infundibula due to incomplete cementogenesis.
- Centric occlusion (central occlusion)** – Relationship of the occlusal surfaces of one dental arch to those of the other when the jaws are closed and the teeth are in maximum intercuspation.
- Cephalic** – Relating to the skull or head.
- Cephalometrics** – Anatomical measurements of skull structures.
- Cheeks** – Lateral boundaries of the oral cavity.
- Cheek teeth** – An equine term to describe premolars 2-4 and the three molar teeth.
- Cheilitis** – Inflammation of the lips.
- Choke** – Esophageal obstruction.
- Chondrosarcoma** – Malignant tumor of cartilage.
- Chronic** – A process continuing over a long period of time (e.g., many months). The opposite of acute.
- Cingulum** – A convexity on the surface of a tooth – used loosely to describe the vertical ridges on the buccal aspects of maxillary cheek teeth.
- Cleft palate** – Lack of joining together of hard or soft palate.
- Clinical crown (erupted crown)** – The part of the crown that lies outside of the alveolus and gingiva (i.e., the part that is visible in the oral cavity).
- Colic** – Pain related to abdominal, primarily alimentary disease.
- Commissure** – Junction of the upper and lower lip at the angle of the mouth. Band of tissue joining two parts or organs together.
- Complex or compound odontoma** – Mixed odontogenic tumor composed of both epithelial and mesenchymal cells in a disorganized mass that contains no tooth-like structures. Can have a cystic component.
- Composite** – Type of dental restorative material typically composed of an organic polymer matrix of high molecular weight, usually bisphenol A-glycidyl methacrylate (bis-GMA) resin, with or without fillers.
- Concha** – Any body structure that resembles a shell in shape (e.g., the nasal turbinate bone).
- Condylectomy** – Excision of condylar process of the mandible.
- Condylod process** – That portion of the vertical ramus of the mandible that is part of the temporomandibular joint.
- Congenital** – Denoting a condition usually abnormal, present at or before birth, but one that is not necessarily hereditary.
- Contrast** – Radiography relates to the variation in the black and white density on areas of radiographic images.
- Coprophagy** – The act of eating feces.
- Coral formation** – Colloquial term. Metaplastic calcification of the conchal cartilage caused by chronic sinus infection.
- Corona** – Tooth crown.
- Coronal** – Direction toward the crown. Relating to or towards the crown part of a tooth.
- Coronoid process** – Bony projection at the dorso-rostral portion of the vertical ramus. It is the attachment location for the temporal muscle.
- Cortex** – The external layer of an organ or bone; hence, cortical.
- Cranial nerves** – Nerves of the head.
- Craniofacial deformity** – Skull and face deformities. May be developmental or acquired.
- Crest** – As pertains to radiation, the height of the wave.
- Crib-biting (cribbing)** – Destructive behavior when horses bite their food containers or surroundings resulting in an abnormal wear pattern to their incisors and possibly may also be associated with the ingestion of air.
- Cribiform plate** – Dense bone that forms the wall of the alveolus. Cribiform plate also refers to the horizontal lamina of the ethmoid bone.
- Crown** – 1) The part of the tooth which contains enamel (both clinical crown and reserve crown), i.e., all of the tooth except the roots, which by definition contain no enamel. 2) A restoration that covers part or the entire clinical crown.
- Crypt** – Term used to describe the early tooth socket.
- Cryosurgery** – Surgical destruction by freeze/thaw cycles. Using liquid nitrogen.
- Cup** – Hollow structure with open top.
- Curvature of Spee** – Rising slope of caudal aspects of the mandible, and thus of the occlusal surface of the caudal mandibular cheek teeth.
- Cusp** – 1) A pronounced elevation on the occlusal surface of a tooth terminating in a conical, rounded, or flat surface. 2) Any crown elevation that begins calcification as an independent center.
- Cyanoacrylate** – Adhesive material, usually self-curing in the presence of moisture in an anaerobic environment.
- Cyst** – Sac of fluid lined by epithelial cells; it may grow to varying sizes.
- Debridement, dentistry** – The removal of debris from a dental cavity in an alveolus or root canal. The surgical removal of cellular debris from the surface of a wound.
- Decay** – The decomposition of organic matter.
- Deciduous teeth** – The first dentition; milk teeth. *See* Primary teeth.
- Deglutition** – Action of swallowing.
- Dehiscence** – The spontaneous breakdown of a surgical wound.
- Dens** – Tooth.
- Dens in dente (tooth within a tooth)** – Developmental disorder that is formed when the top of the tooth bud folds into itself, producing additional layers of enamel, cementum, dentin, or pulp tissue inside the tooth as it develops.
- Dens invaginatus** – A developmental anomaly involving an invagination on the lingual or palatal surface of an incisor.
- Dental arch** – All teeth forming an arch in either the maxillary or mandibular jaw in species with true dental arches – correctly should only refer to the equine incisors that do form a true arch.
- Dental attrition** – The wear or loss of tooth substance due to normal masticatory and prehension forces.
- Dental cap, colloquial** – The remains of a horse's deciduous premolars once the roots have been resorbed.
- Dental lamina** – Embryonic downgrowth of oral epithelium that is the forerunner of the enamel bud.

- Dental papilla** – Mesodermal structure partially surrounded by the inner enamel epithelial cells that later form the dentin and pulp.
- Dental sac** – Layers of flat mesodermal cells partially surrounding the dental papilla and enamel organ. It forms the cementum, periodontal ligament, and some alveolar bone.
- Dental star, colloquial term** – Occlusal appearance of secondary dentin in equine incisors.
- Dentes canini** – Canine, cuspid, eye, or fang teeth.
- Dentes decidui** – Deciduous teeth.
- Dentes incisivi** – Incisor teeth.
- Dentes molares** – Molar teeth.
- Dentes permanentes** – Permanent teeth.
- Dentes premolares** – Premolar teeth.
- Denticles** – Small, tooth-like structures.
- Dentigerous** – Containing teeth or tooth-like structures.
- Dentigerous cyst** – Developmental dental follicle remnant with ectopic, cystic tooth-like structure usually lying on the temporal bone.
- Dentin (dentine)** – A soft (ivory like) component of the mineralized tooth that increasingly fills the pulp chamber with age (e.g., with secondary dentin).
- Dentinal tubules** – Linear, tube-like spaces in the dentin that are occupied by the odontoblastic processes.
- Dentinoenamel junction (DCJ)** – *See* CDJ.
- Dentinoenamel junction (DEJ)** – Junction where the dentin and enamel tissues meet.
- Dentinogenesis imperfecta** – A hereditary condition in which dentin is abnormally formed, leading to generalized dental dysplasia.
- Dentition** – General character and arrangement of the teeth, taken as a whole, as in carnivorous, herbivorous, and omnivorous dentitions. Mixed dentition refers to a combination of permanent and deciduous teeth in the same dentition.
- Dermatitis** – Inflammation of the skin and subcutis.
- Developer** – Radiography solution to make the latent image on an exposed X-ray film visible.
- Diarthrodial joint** – Movable joints.
- Diastema (plural, diastemata)** – A space between teeth. In the horse refers both to the physiological space between the incisors and premolars (the interdental space) more commonly to the pathological presence of an abnormal space between adjacent teeth.
- Digastric muscle** – Paired muscles from jugular process of occipital bones to mandible. Opens the mouth.
- Digestive tract** – gastrointestinal tract
- Diphyodont** – The feature of having two sets of teeth, one designated deciduous or primary and the other permanent. The teeth of most domesticated animals and humans are diphyodont.
- Disarming, veterinary** – Procedure where one or more teeth are either extracted or shortened in order to prevent animals from inflicting injuries.
- Distal** – Farthest away from a median line of the face – useful term for brachydont teeth.
- Dolichocephaly** – Condition marked by a long, narrow facial profile.
- Domestication** – Adjustment of animals to living with humans; taming.
- Dominant** – An allele that produces an effect on the phenotype even when present in a single dose.
- Dorsal** – Toward or situated on the top.
- Dorsum of the tongue** – Top surface of the tongue.
- Duplicidentata** – Double-row dentition.
- Dysmastication** – Difficulty chewing.
- Dysphagia** – Difficulty swallowing.
- Dysphrehension** – Difficulty grasping food with lips and teeth.
- Dysplasia** – Abnormal development of a part or organ.
- Dyspnea** – Difficulty in breathing.
- Ectoderm** – Outer embryonic germ layer that forms skin, salivary glands, hair, sweat glands, sebaceous glands, nerves, etc.
- ectomy (suffix), medicine** – Excision of a part.
- Edentate** – Lacking teeth – due to absence of their development or their later loss in the horse. Some other species are normally edentulous (toothless).
- Elevator** – Instrument used to elevate the tooth or root section out of the alveolus during extraction.
- Empyema** – The accumulation of pus in a hollow organ or body cavity.
- Emphysema** – The abnormal presence of gas in a part of the body.
- Enamel** – A calcified dental tissue which is the hardest substance in the body, and provides great wear resistance for teeth.
- Enamel cuticle (Nesmith's membrane)** – A thin membrane that covers the crown of a tooth at eruption.
- Enamel hypoplasia** – Condition in which the enamel layer is thin or reduced.
- Enamel lamellae** – A hypomineralized structure in teeth that extend from the dentinoenamel junction to the surface of the enamel.
- Enamel organ** – Ectodermal (epithelial) structure that leads to the formation of tooth enamel.
- Enamel pearls (enamelomas)** – Small enamel growths on the root of the teeth; considered abnormal structures.
- Enamel prisms** – Basic enamel unit running from the dentinoenamel junction to the surface of enamel.
- Enamel rod** – Individual pillars of enamel formed by ameloblasts.
- Endo- (prefix)** – Within.
- Endoderm** – Inner germ layer of an embryo that forms the epithelial lining of organs such as the digestive tract, liver, lungs, and pancreas.
- Endodontics** – Branch of dentistry involved with treating the pulp and root canals.
- Endoscope** – Instrument used for examining inside hollow organs and the abdominal cavity.
- Endoliths** – Calcifications within the endodontic system; more commonly referred to as pulp stones.
- Epistaxis** – Hemorrhage from the nose.
- Epithelial attachment** – Interface at the base of the gingival sulcus or periodontal pocket that unites the gingiva to the tooth.
- Epithelium** – Cellular layer that covers the external and internal surfaces of the body or organs.
- Epulis** – Any type of benign growth situated on the gingiva.
- Erosion** – External loss of calcified dental tissue due to a chemical process without active bacterial involvement.
- Eruption of teeth** – The process of movement of tooth from the alveolus into the oral cavity.
- Eruption cysts (pseudocysts) ("3 or 4 year old bumps")** – Enlarged areas of soft tissue at the developing apices of immature permanent cheek teeth. These cysts can cause bony swellings on the ventral surface of the mandible, less commonly on the maxillary bones, in 2–4 year old horses.
- Eruption times** – Times for anticipated eruption of teeth.
- Eruptive stage** – Period of eruption from the completion of crown formation until the teeth come into occlusion. The prefunctional eruptive stage occurs at the beginning, before the teeth move into occlusion.
- Exfoliation** – Shedding or loss, e.g., of a primary tooth.
- Exodontia** – Extraction of teeth.
- Exostosis (pleural exostoses)** – Local deposition of new bone that projects beyond the normal limits of the skeleton.
- Exothermic** – A chemical reaction that generates heat.
- External fixation** – Methods by which fractured bones are supported by devices outside the body.

- External fixator** – Device with which fractured bones are immobilized using percutaneous pins that are joined outside the body.
- Extirpate** – To completely remove or destroy a part or organ.
- Extirpation** – Complete surgical removal or destruction of a tissue, such as a pulp.
- Extra-oral** – Outside the mouth.
- Extract** – To pull out or remove.
- Extrinsic** – Originating outside a structure.
- Extrusion** – Movement of a tooth further out of the alveolus, typically in the same direction as normal eruption.
- Eye teeth** – *See* cuspid.
- Facial nerve** – Cranial nerve VII, innervating the facial muscles of expression and caudal belly of the digastric muscle.
- Facultative anaerobes** – Bacteria that can live in either aerobic or anaerobic conditions.
- Familial** – Used to describe conditions that affect a family to an extent that is considered greater than expected by random chance or circumstance.
- FDI system** – System for tooth identification promulgated by the Federation Dentaire Internationale (International Dental Federation).
- Fetid** – Having a smell of decaying matter.
- Fibroma** – Benign tumor of mesodermal origin.
- Fibrosarcoma** – Malignant tumor of fibrous connective tissue.
- Fibrous dysplasia** – Incomplete differentiation of fibrous tissues. Replacement of bone as a result of parathyroid dysfunction.
- Filliform papillae** – Small pointed projections pointing caudally that heavily cover most of the dorsum of the anterior two-thirds of the tongue.
- Filing Dentistry** – Grinding or rasping of dental tissues.
- Fissure** – A small crack, e.g., an enamel fracture in a cheek tooth.
- Fistula** – A tract (duct) leading from an internal cavity in the body to the surface or from one body cavity to another, e.g., from a paranasal sinus to the mouth (oromaxillary fistula) or from the oral to the nasal cavity (oronasal fistula). A tract connecting two epithelialised surfaces.
- Fixer solutions** – Radiography chemicals used to preserve and enhance the latent image on a radiographic film.
- Flap** – Portion of mucous membrane or skin separated from the surrounding tissues except for at least one edge.
- Floating** (*see also* Rasping). **Veterinary** – The process of smoothing down the sharp buccal or lingual enamel overgrowths (“points”) on the cheek teeth of horses. The act of using rasps to remove sharp edges from teeth.
- Fluorosis** – Disruption in the mineralization of developing teeth due to excess ingestion of fluoride, often seen as chalky white spots or discoloration of the enamel.
- Focal film distance (FFD)** – Distance from the focal spot on the tube’s target to the film.
- Follicle** – Fibrous sac which surrounds the developing tooth germ and by which it is attached to the oral mucosa.
- Follicular cyst** – Dentigerous cyst or dilation of the follicular space around the crown of a tooth that is unerupted or impacted.
- Foramen** – A small circular opening or passage, e.g., where the mental nerve leaves the mandible.
- Frenulum** – Fold of tissue that limits the movement of an organ (e.g., frenulum under the tongue or between lips and gums).
- Fulcrum** – Dentistry. A device used to increase leverage of dental equipment during extractions
- Functional occlusion** – Active tooth contact during mastication and swallowing; also called dynamic occlusion.
- Furcation** – Point at which roots diverge. Teeth with multiple roots have bi- or trifurcation.
- Gag** – Speculum – An instrument to prevent the closure of the mouth during oral examination or surgery.
- Galvayne’s groove** – A groove in the labial surface of 103/203 (upper permanent corner incisor of the horse) which was believed begin to appear at approximately 10 years, is half way down at 15, fully down at 20, half worn away at 25 and absent at 30 years of age. This feature has been shown to give an inaccurate indication of age.
- Gamma radiation** – Radiation of the same approximate wavelength as X-radiation that is naturally occurring rather than man-made.
- Germination** – Dental disorder in which the developing bud attempts to split but fails to do so completely, resulting in duplication of part of the tooth but not total twinning.
- Gene** – A unit of information in DNA that codes for a particular disease or trait.
- General anesthesia** – Controlled, drug-induced unconsciousness, whereby pain, voluntary muscle movement and an effective swallowing reflex are eliminated.
- Genetic** – Term describing the condition of being hereditary.
- Genotype** – The genetic makeup of an animal.
- Gingiv- or gingivo- (prefix)** – Denoting the gingiva.
- Gingiva** – Keratinized oral membrane that immediately surrounds the teeth and alveolar bone.
- Gingival** – Of or pertaining to the gums.
- Gingival crest** – Most occlusal extent of gingiva.
- Gingival crevice (sulcus)** – Subgingival space that under normal conditions lies between the gingival crest and the epithelial attachment to the adjacent peripheral cementum.
- Gingival fibers** – Periodontal fibers in the gingiva.
- Gingivitis** – Inflammation of the gums.
- Glass ionomers** – Dental restorative compounds that chemically bind to enamel and dentin by ions forming salts that bond to the calcium in the tooth, even if slight moisture is present.
- Glossectomy** – Surgical removal of part or all of the tongue
- Glossitis** – Inflammation of the tongue.
- Glossoplegia** – Paralysis of the tongue, either unilateral or bilateral.
- Gnathic** – Relating to the jaw, meaning the mandible in modern usage.
- Granuloma** – Localized mass of reactive tissue containing macrophages associated with an area of chronic suppuration and/or healing.
- Gutta percha** – An ionomer of rubber extracted from the sap of certain tropical trees. Endodontic filling agent that is about 60% crystalline and slightly viscoelastic.
- Halitosis** – Malodorous or foul breath.
- Hard palate** – Bony vault of the oral cavity proper covered with soft tissue.
- Hard tissue** – Calcified or mineralized dental tissues or bone.
- Hausmann gag** – A metal-framed, ratchet-operated device used to keep the mouth of horses open for examination or treatment.
- Haversian system** – System of blood vessels located within bones.
- Hemimandibulectomy** – Excision of half of the mandible.
- Hemisection** – To cut in half.
- Hemostasis** – To arrest hemorrhage.
- Hereditary** – Genetically determined; passing or capable of passing from parents to offspring.
- Hertwig’s epithelial root sheath** – A downgrowth of the inner and outer enamel epithelium that initiates dentin formation.

- Heterodont** – The feature of having more than one type (size, shape) of tooth represented in the dentition, such as incisors, canines, premolars, and molars.
- Homodont** – The feature of having all teeth that are of the same general shape or type, although size may vary.
- Hook** – Colloquial term for a sharp narrow overgrowth developed on a tooth through abnormal wear, e.g., on 06s or 11s. Also note 7- or 9-year incisor “hooks”, now shown to be inaccurate for age determination.
- Horizontal ramus** – That portion of the jaw composed of the body and symphyseal area of the mandible.
- Hydroxyapatite (hydroxylapatite)** – Calcium- and phosphate-containing crystals found in hard substances of the body, such as bone, cementum, dentin, and enamel.
- Hyoid apparatus** – Bony structure originating from 2nd and 3rd branchial arches. Attached to petrous part of temporal bones and supports the root of the tongue, pharynx, and larynx.
- Hyper- (prefix)** – Exaggerated, excessive.
- Hypercementosis** – Increased thickness of cementum, usually seen at the apex of the tooth.
- Hyperemia** – Congestion of blood, as may be seen in pulp.
- Hyperplasia** – Enlargement or overdevelopment of organ or tissue through increased production of cells.
- Hyperplastic** – Affected by hyperplasia.
- Hyperptyalism** – Excess salivation.
- Hypodontia** – Condition in which some teeth are missing although the term anodontia is often loosely used in this regards.
- Hypoplasia** – Reduced or inadequate tissue formation.
- Hypoplastic enamel** – Thin enamel, commonly seen in conjunction with enamel hypocalcification. *See* enamel hypoplasia.
- Hypsodont** – Teeth which have a limited growth period but prolonged eruption (in contrast, elodont teeth, as in rabbits, have permanent growth and eruption throughout life; brachydont teeth, such as humans have a limited growth and limited eruption time).
- Iatrogenic** – Induced injury that is caused by or created by treatment, e.g., fractures of 311 or 411 using a guillotine or fractures of cheek tooth caused by dental shears.
- Idiopathic** – Disease of unknown origin.
- Impacted teeth** – Teeth which have been prevented from erupting by mechanical obstruction, usually compression from the two adjacent teeth. Impactions may cause large eruption cysts to develop at the apex of the impacted tooth and focal hard swellings (‘3- and 4-year-old bumps’) on the mandible or maxilla.
- Implant dentistry** – Intra-osseous, biocompatible structure placed in the alveolar bone, which is used as a support in prosthodontics.
- Impression** – Mold taken of the teeth and/or intra-oral contours of the jaw for the preparation of a replica model.
- Impression material** – A substance used in the making of a mold of the teeth and/or the contours of the jaw.
- Impression tray** – Receptacle, usually custom-made in veterinary use, to fit the jaw being treated for carrying the impression material.
- Incisal** – Occlusal direction in incisors.
- Incisal bone** – *See* Incisive bone.
- Incisivomaxillary suture** – Articulation of the incisive bone and the maxillae.
- Incisors** – Teeth found at the front of the horse’s mouth (e.g., all teeth embedded in the premaxilla are incisors by definition, as are those situated in the rostral mandible). Incisors are used for grasping (prehension) of food. In horses there are normally 12 deciduous and 12 permanent incisors (Triadan 101–3; 201–3; 301–3; 401–3).
- Incisive bone (premaxilla incisal bone)** – The bone attached to the rostral aspect of the maxilla which bears the upper incisors.
- Incline planes** – Orthodontic appliances designed to make contact with the cusps or incisal edges of the teeth of the opposing occlusion to stimulate tooth movement directed by the inclination.
- Inferior** – Indicating the relative position of a structure that is lower than others.
- Inflammation** – Reaction of living tissue to infection or injury.
- Infra- (prefix)** – In anatomy, indicating a position beneath the structure being qualified. In dentistry, indicating a position apical to the structure being qualified.
- Infundibulum** – Enamel infoldings found in centers of incisor and the upper cheek teeth that are filled (or partially filled) with cementum. The single incisor infundibulum is colloquially termed the ‘cup’. There are two infundibula in each upper and none in the lower cheek teeth.
- Insidious** – Slow or gradual onset. Refers to a disease and indicates that it does not exhibit early symptoms of its onset or progress.
- Interceptive orthodontics** – Generally considered to be the extraction or recontouring (crown reduction) of primary or permanent teeth that are contributing to alignment problems of the permanent dentition.
- Interdental** – Located between teeth.
- Interdental (interproximal) space** – The space between two adjacent teeth. Also used to describe the space between equine incisors and cheek teeth (e.g., ‘bars of the mouth’).
- Internal fixation** – Surgical stabilization of fracture with pins, plates, screws, etc. attached within the affected bones.
- Interproximal** – *See* interdental.
- Interproximal space** – *See* interdental space.
- Interradicular septa** – Obsolete term for interalveolar septa, i.e., Bony partitions between adjacent teeth.
- Intradental oral cavity (IDOC)** – Space whose boundaries are the lingual and palatal margins of the teeth.
- Intrinsic** – Lying entirely inside a structure.
- Intrinsic muscles of the tongue** – Muscles that produces the complicated protrusion and prehensile movement of the tongue. They are innervated by the hypoglossal nerve.
- Isognathism** – Condition of having equal jaw widths, in which the premolars and molars of opposing jaws align with the occlusal surfaces facing each other.
- Jaw** – The upper jaw is formed by the premaxilla (incisive) and maxillary bones and the lower jaw is formed by the mandibular bone; both jaws contain the teeth.
- Juvenile ossifying fibroma** – Benign, locally invasive, gingival tumor.
- Keratin** – Substance contained by the surface cells of skin, hair and hooves.
- Labium (pl. labia)** – Latin for ‘lip’.
- Labial** – Of or pertaining to the lips. Also, as a direction, towards the lips or the rostral aspect of mouth.
- Lamina dura** – Radiographic term denoting the cribriform plate, bundle bone, and the dense alveolar bone surrounding the reserve crown and roots.
- Lampas** – Physiologically normal swelling of the mucosa of the hard palate, often greatest just behind the upper incisors especially in young horses.
- Lateral** – Away from the median plane (is the opposite of medial); refers to the buccal aspect (outside) of teeth. A position farther from the midline of the body or median plane. Opposite of medial.
- Lateral excursion** – Lateral movement of the mandible relative the maxilla.

- Lateral excursion to separation** – A measure of cheek teeth occlusion and occlusal angulation. This term refers to the point during lateral excursion of the mandible with the jaws closed when the angled occlusal surface of the cheek teeth causes separation of the incisors.
- Ligament** – Regularly arranged group of collagen fibers.
- Lingual** – Referring to the tongue; also, as a direction, towards the tongue, used to refer to medial aspect of the mandibular cheek teeth (palatal refers to identical aspect of maxillary cheek teeth).
- Lingual arteries** – Primary blood supply to the tongue.
- Lingual frenum** – Fold of tissue that attaches the undersurface of the tongue to the floor of the mouth.
- Lingual mucosa** – Thick, rough, keratinised mucous membrane covering the dorsum of the tongue.
- Lips** – Most rostral extent of the oral cavity. The upper and lower lips converge at the angles of the mouth to form its commissures.
- Lophodont** – The feature of having teeth that have a lamellar structure of longitudinal layers of enamel and dentin that become fused with cementum, with cusps that connect to form ridges, as in the cheek teeth of the rhinoceros and elephant.
- Luxation** – Partial or complete dislocation from a joint, as in the temporomandibular joint or of a tooth from its alveolus.
- Lysis** – Dissolution or breaking down.
- Macrodonia** – Teeth that are developmentally disproportionately large.
- Macroglossia** – Oversized or large tongue.
- Malar** – Relating to the zygoma, cheek bone.
- Malignant** – Term to describe tumors that show an uncontrollable growth and destructive growth pattern of the tissue of origin and that may exhibit metastasis.
- Malocclusion** – Faulty occlusion; abnormal contact of opposing upper and lower teeth.
- Maleruption** – Improper eruption of tooth/teeth.
- Malformation** – Failure to develop properly.
- Mandible** – The lower jaw bone formed by the fusion of the two hemimandibles at the symphysis.
- Mandibular** – Pertaining to the mandible.
- Mandibular alveolar block** – Regional anesthetic nerve block achieved by blocking the mandibular nerve as it enters the mandibular canal on the medial aspect of the mandible.
- Mandibular arch** – First branchial arch that forms the mandible and maxillae.
- Mandibular condyle** – Rounded top of the mandible that articulates with the mandibular fossa.
- Mandibular foramen** – Opening on the medial surface of the vertical ramus of the mandible for entrance of nerves and blood vessels to the lower teeth.
- Mandibular fossa** – Depression on the inferior surface of the skull in the temporal bone that articulates with the condyle of the mandible.
- Mandibular symphysis** – Point at which the two hemimandibles merge, forming the mandible.
- Masseter muscle** – Muscle of mastication arising from the zygomatic arch and inserting on the lateral ramus of the mandible. It acts to close the mandible.
- Mast cell** – Mesodermal cell containing granules that release histamine in inflammatory reactions.
- Mastication** – The grinding of food by the teeth.
- Masticatory mucosa** – Mucosa (parakeratinized or keratinized) of the hard palate and gingiva.
- Masticatory surface** – Occlusal surface of teeth.
- Maxilla** – One of the paired bones of the upper jaw which contain the two rows of upper cheek teeth and also contain the maxillary sinuses and contributes to the hard palate.
- Maxillary** – Of or pertaining to the maxilla.
- Maxillary cheek teeth row** – Upper cheek teeth.
- Maxillary sinuses** – Paired paranasal sinuses located in the maxillae.
- Maxillofacial** – Structures including and covering maxillary and facial bones.
- Meatus** – A naturally occurring canal or channel.
- Medial** – Opposite of lateral.
- Medial pterygoid muscles** – Muscles of mastication arising from the sphenoid bone and inserting on the condyle and articular processes of the mandible. They serve to close the mandible.
- Median line** – Vertical line that divides the body into right and left (e.g., the median line of the face).
- Median plane** – A plane running vertically (dorsoventrally) down the midline of a horse from nose to tail.
- Median raphe** – Midline of the palate dividing the right and left sides.
- Melanoma** – Mesodermal origin tumor containing pigment bearing melanocytes.
- Mental** – Relation to the chin.
- Mental foramen** – Foramen on the lateral side of the mandible, below the premolars.
- Mental regional block** – Regional anesthetic nerve block achieved by injection at the mental foramen. It provides analgesia to the incisors, canines, and possibly the lower 06.
- Mesaticephaly** – Condition marked by a head shape of medium proportions.
- Mesenchymal cells** – Embryonic connective tissue that begins the development stage of the dental papilla and the dental sac.
- Mesenchyme** – Connective tissue derived from mesoderm.
- Mesial** – Toward or situated in the middle (e.g., toward the midline of the dental arch).
- Mesial drive** – Phenomenon in brachyodont dentition in which the permanent molars continue to move mesially after eruption. In equine teeth, the caudally facing 06s cause a caudal movement of the rostral cheek teeth.
- Mesocephaly** – Condition marked by a balanced facial profile, somewhere between dolichocephalic and brachycephalic.
- Mesoderm** – Middle germ layer of the embryo that forms connective tissue, muscle, bone, cartilage, blood, etc.
- Metaplasia** – The transformation of one type of tissue into another.
- Metaplastic calcification** – Pathological deposition of calcium in soft tissues.
- Metastasis** – Dissemination of tumor cells to other parts of the body.
- Methyl methacrylate** – Liquid monomer used in the manufacture of acrylic resins by mixing it with a powder polymer.
- Microdonia** – Teeth that are disproportionately small.
- Microglossa** – A small tongue.
- Midline** – Imaginary line that divides the body into right and left halves.
- Midsagittal plane** – Imaginary plane that divides the body vertically into right and left halves.
- Mixed dentition** – The feature of having primary and permanent teeth in the dental arches or rows at the same time.
- Molarization** – Changes in the appearance of premolar teeth to resemble molar teeth.
- Molars** – Grinding cheek teeth that have no deciduous predecessors in the dental arcades (e.g., the last three cheek teeth). (Triadan 109–11; 209–11; 309–11; 409–11.) The term molars is also wrongly used to refer to all 6 cheek teeth.

- Monkey mouth** – Colloquial term for sow" mouth. Prognathism, Protruding mandible.
- Monophyodont** – The feature of having only one set of teeth that erupt and remain functional throughout life, i.e., there are no deciduous teeth.
- Morphology** – Study of the form and structure of an organism or part of it.
- Mottled enamel** – Enamel that is opaque or chalky and may be discolored due to its porous nature.
- Mouth** – Entrance to the oral cavity.
- Mouth speculum** – Mechanical device used to hold the mouth open.
- Mucobuccal fold** – Point at which the oral mucosa and the top or bottom of the vestibule turn toward the alveolar ridge.
- Mucocele** – See sialoceles.
- Nares** – Nostrils.
- Nasal septum** – Cartilaginous wall between the left and right sides of the nasal cavity, made up of the ethmoid and vomer bones.
- Nasmyth's membrane** – Membrane covering the surface of the tooth crown at the time of eruption.
- Necrosis** – The death of organic tissue; hence, necrotic.
- Neoplasia** – A new growth or tumor.
- Neoplasm** – Benign or malignant tumor; morbid mass of tissue growing at an abnormal rate.
- Newborn gingival cyst** – Cyst arising from the remnants of dental lamina in newborn animals.
- Non-successional (non-succedaneous) teeth** – Permanent teeth (classically molars) that do not succeed a deciduous counterpart.
- Object film distance (OFD)** – Distance between the film and the object during radiography. Minimizing OFD can reduce distortion.
- Obturation** – The process of filling, packing, as in endodontic filling of pulp cavities.
- Occluding** – Contacting opposing teeth.
- Occlusal** – Articulating or biting surface.
- Occlusal plane** – Side view of the occlusal surfaces.
- Occlusal relationship** – Way in which the maxillary and mandibular teeth touch each other.
- Occlusal surface** – Surface of a tooth within the marginal ridges that contacts the corresponding surfaces of antagonists during closure of the mouth.
- Occlusion** – Surface-to-surface contact between opposing teeth.
- odontics (suffix)** – Indicating a dental subject or discipline.
- Odonto- or odont- (prefix)** – Relation to teeth; indicating toothed.
- Odontoblast** – Dentin-forming cell that originates from the dental papilla.
- Odontoblastic cell layer** – Layer in the pulp that is closest to dentin.
- Odontoblastic process** – Cellular extension of the odontoblast, extending along the length of the dentinal tubules.
- Odontogenic cyst or tumor** – Lesions arising from cellular components of the developing tooth structure.
- Odontoma** – Mixed odontogenic tissue tumor containing both epithelial and mesenchymal cells. It may be either compound (disorganized mass) or complex (with denticles).
- Oligodontia** – The absence of one or more teeth.
- oma (suffix)** – Indicating a tumor.
- Opaque** – Not easily able to transmit light.
- Open fracture** – A fracture where there is a breach in the overlying skin or mucous membranes.
- Operculum** – Persistence of a thick, fibrous gingiva over a partially or even fully erupted tooth.
- Oral cavity (cavum oris)** – Area extending from the lips to the oral pharynx at the level of the palatine tonsil.
- Oral cavity proper** – Area extending from the alveolar ridge and teeth to the oral pharynx. It does not include the vestibule.
- Oral mucosa** – Stratified squamous epithelium running from the margins of the lips to the area of the tonsils and lining the oral cavity; also known as oral mucous membrane.
- Oral mucous membrane** – See oral mucosa.
- Organic matrix** – Non-calcified framework in which crystals grow.
- Oro- (prefix)** – Combining form indicating oral, mouth.
- Oronasal fistula** – An opening between the oral and nasal cavities – usually is a complication of extraction or periapical abscess of one of the 1st three upper cheek teeth.
- Oropharynx** – Area between the soft palate and the base of the tongue.
- Ortho- (prefix)** – Straight.
- Orthodontic acrylics** – Materials used to form a framework or base structure from which various inclines, springs, arch wires, or expansion devices can be attached.
- Orthodontics** – That area of dentistry concerned with the supervision and guidance of the growing dentition and correction of the mature dentofacial structures. It involves those conditions that require movement of teeth and/or correction of malrelationships of the jaws and teeth and malformations of their related structures.
- Orthognathic surgery** – Surgery of mandibles to correct tooth alignment.
- Osteoconductive** – Characteristic of a product that aids in regenerating new bone in an osseous site. Almost all guided tissue regeneration products are osteoconductive.
- Osteoinductive** – Characteristic of a product that aids in the generation of new bone in any site, even muscle tissue. Autogenous bone grafts and bone morphogenetic protein can do this; however, freeze-dried bone and irradiated bone are not osteoinductive because the necessary cells have been killed by treatment of this product.
- Osteointegration** – Process in which a material's surface becomes attached or bonded to bone; also known as functional ankylosis. In the process, metal oxides on the surface of an implant bond to bone.
- Osseous wiring** – Placement of wires in direct contact with bone to provide reduction and support to segments of a bony fracture.
- Ostectomy** – Removal of osseous defects and infrabony pockets by the removal of bony pocket walls.
- Osteo- (prefix)** – Indicating bone.
- Osteoblasts** – Cells that form bone.
- Osteoclasts** – Multinucleated cells responsible for destroying bone.
- Osteocytes** – Osteoblasts that have surrounded themselves with bone.
- Osteogenic** – Bone producing.
- Osteoid** – Bone-like.
- Osteoma** – Benign bone tumor.
- Osteomyelitis** – Infection of bone marrow.
- Osteoplasty** – Shaping of bone to restore its physiologic contour.
- Osteosarcoma** – Osseous tumor that can develop on the mandible or maxilla that is locally invasive but has less metastatic potential than its counterpart in the appendicular skeleton.
- Osteotome** – Bone cutting chisel.
- Osteotomy** – Surgical operation of cutting through a bone.
- Overbite** – Relationship of the teeth in which the incisal edges of the maxillary anterior teeth extend below the incisal edges of the mandibular anterior teeth when the teeth are placed in a centric occlusal relationship.
- Overjet** – See overlap, horizontal.
- Overlap, horizontal (overjet, overjut)** – Rostral projection of the upper anterior and/or posterior teeth beyond their antagonists in a horizontal direction.
- Overshot** – See Retrognathism.
- Palatal** – Pertaining to the palate or roof of the mouth.
- Palatal surface** – Lingual (medial) surface of the maxillary teeth.

- Palate** – Roof of the mouth is formed by the hard palate to level of 111, 211 where it then joins the soft palate.
- Palatine artery** – Large artery that lies just medial to the upper arcades of cheek teeth at the edge of the hard palate.
- Palatine rugae**, *See rugae*.
- Palliative** – Treatment that alleviates the severity of pain or disease without curing it.
- Papilla** – Small nipple-like process.
- Paranasal** – Around the nose, as in paranasal sinuses.
- Parotid duct** – Duct formed by two to three tributaries from the parotid salivary gland. It opens into the mouth at the parotid papilla at the level of the caudolateral root of the maxillary fourth premolar.
- Parotid salivary gland** – ‘V’-shaped salivary gland located beneath the ear and behind the caudal border of the mandible and the temporomandibular joint. It has superficial and deep portions. *See* parotid duct.
- Partial anodontia** – Hypodontia, i.e., Condition in which some but not all of the teeth are missing.
- Parrot mouth** – Overbite, overjet, mandibular brachygnathism.
- Passive eruption** – Condition in which the tooth does not move but the gingival attachment moves apically.
- Pathologic movement** – Orthodontic tooth movement that occurs when a heavy force is exerted, resulting in necrosis of periodontal tissues on the pressure side and poor to no deposition of bone on the traction side.
- Peg tooth** – A small tooth with a cone-shaped crown. *See also* microdontia.
- Pellicle** – A thin film of salivary proteins found on the clinical crown of teeth.
- Percutaneous** – Through the skin.
- Percutaneous skeletal fixation** – Use of pins or wires extending from fracture fragments and secured externally with an additional device (e.g., rod or acrylic tubing).
- Peri- (prefix)** – Around.
- Periapical** – Around the apex of a tooth or the root in a mature tooth.
- Periapical abscess** – Active infection around the apex, with suppuration.
- Periapical cyst** – Cystic reaction around the root tip in mature tooth, often developing from epithelial cells from the rests of Malassez.
- Periapical granuloma** – Granulomatous reaction around the apex without demonstrable bacteria.
- Pericoronitis** – Inflammation of the gingiva.
- Periodontal** – Literally means ‘around or near the teeth;’ surrounding a tooth; usually used to refer to gums or the other soft tissues (periodontal membrane/ligaments). Also refers to the alveolus.
- Periodontal disease** – Inflammation of the gingiva or periodontium.
- Periodontal ligaments** – Tough fibers which secure the cement on the periphery of the tooth to the bony alveolus; act as shock absorbers to dampen occlusal pressures.
- Periodontal membrane** – *See* Periodontal ligament.
- Periodontal pocket** – Space created by periodontal erosion of gingival sulcus.
- Periodontal probes** – Flat or round-tipped instruments that have various lengths in millimeters marked on them.
- Periodontitis** – An active disease state of the periodontium.
- Periodontium** – Supporting tissues surrounding the teeth.
- Periodontology or Periodontics** – Area of dentistry concerned with the study and treatment of the diseases involving the gingivae and the supporting tissues of the teeth.
- Periosteum** – Tough elastic membrane covering the surface of bones; fibrous and cellular layer covering bones and containing cells that can become osteoblasts.
- Periradicular osteomyelitis** – Radiographic osteopenia and expansion effects of the alveolus seen in some cases of chronic pulpal inflammation.
- Peritubular dentin** – Dentin immediately surrounding the tubule. It is slightly more calcified than the rest of the dentin.
- Permanent teeth (dentes permanentes)** – Final or lasting set of teeth that are typically of a very durable and lasting nature (opposite of deciduous).
- Phenotype** – External appearance or performance of an animal.
- Phy- (prefix)** – To generate.
- Physiologic mobility** – Degree of tooth movement that can be considered normal, limited to the width of the periodontal ligament.
- Physiologic movement** – Movement in orthodontic treatment that occurs when a light-to-mild force is applied and acts as a stimulus to initiate cellular resorption on the pressure side and deposition of bone in the tension side.
- Pica** – An intense desire to ingest non-food items.
- Plaque** – A soft coating, essentially bacteria together with some mucins and proteins (*see* Pellicle) that invariably forms on teeth; remains thin if they receive natural cleaning, as most parts do in the horse; builds to great thickness in areas that are not naturally cleaned and is the cause of calculus buildup in these areas. Precursor to buildup of dental calculus and tartar; bacterial/organic/inorganic matrix involved in mineral leaching process.
- Pleurodont** – Tooth that has no root but is attached to the lingual or palatal surface of the jaws.
- Plexus** – A complex network of nerves, blood vessels or lymphatics.
- Pocket** – An abnormally deep defect between the gingiva and the crown or root surface of the tooth.
- Posterior** – Behind or toward the back/caudal part. Situated toward the back, such as premolars and molars.
- Polydontia** – Condition of having supernumerary teeth.
- Posterior teeth** – Teeth of either jaw to the rear of the incisors and canines.
- Prefunctional eruptive stage** – *See* Eruptive stage.
- Prehensile** – Adapted for grasping.
- Premaxilla** – Bony area of the upper jaw that includes the alveolar ridge for the incisors and the area immediately behind it in primates. Also called the incisive bone.
- Premolars** – Permanent teeth that replace the primary molars. Cheek teeth that have deciduous predecessors (Triadan 106–8, 206–8, 306–8, 406–8). Have evolved to be similar to molars of horses. Premolar 1 ‘wolf tooth’ has no predecessor.
- Primary dentin** – Dentin formed from the beginning of calcification until tooth eruption.
- Primary dentition** – Deciduous teeth; also known as first set of teeth (baby teeth, milk teeth). Primary teeth, *see* Deciduous teeth.
- Primordial cyst** – Cyst resulting from the degeneration of the stellate reticulum of the enamel organ, found in place of a tooth.
- Prognathism (underjet)** – Protrusive jaw (‘sow mouth,’ ‘Monkey mouth’); the mandibular incisors are more rostral than the upper incisors. The opposite of brachygnathism.
- Prophylaxis, prophylactic** – Preventive care; in equine dentistry means regular dental maintenance. Also may refer to tetanus antitoxin and antibiotic administration when required.
- Prosthesis** – Artificial device to replace missing natural parts. Dentistry. Crown denture or bridge.

- Proximal** – See approximal. Anatomy. Situated close to the center of the body, the median plane or the point of origin of an organ or limb.
- Ptyalism** – Excessive production of saliva.
- Pulp (dental)** – Highly vascular and innervated connective tissue contained within the pulp cavity of the tooth. It is composed of arteries, veins, nerves, connective tissues and cells, lymph tissue and odontoblasts.
- Pulp canal** – Canal in the root of a tooth that leads from the apex to the pulp chamber. Under normal conditions, it contains dental pulp tissue.
- Pulp cavity** – Entire cavity within the tooth, including the root canal, pulp chamber and horns. See Pulp chamber.
- Pulp chamber or pulp cavity** – Canals in the central portion of tooth that houses connective tissue, nerves and blood vessels and gives vitality to the tooth.
- Pulp exposure** – Unnatural opening of the common pulp chamber or pulp horns by pathological or mechanical means.
- Pulp stones** – Small dentin-like calcifications found in the pulp.
- Pulpal necrosis** – Partial or total pulpal death.
- Pulpectomy** – Extirpation of the entire pulp.
- Pulpitis** – Inflammation of the pulp that may be reversible or irreversible.
- Pulpotomy** – Surgical removal of a portion of the pulp in a vital tooth.
- Purulent** – Condition involving the presence of pus.
- Pus** – Yellow, white or green fluid that is the product of inflammation composed mainly of dead leukocytes, plasma and liquefied tissue cells.
- Pyorrhea** – A lay term denoting periodontal disease.
- Quadrants** – One-fourth of the dentition. The four quadrants are divided into right and left, maxillary and mandibular.
- Quidding** – The term used to describe the dropping of partially masticated boluses of food from the mouth.
- Radicular ankylosis** – Obsolete term for dental ankylosis. Loss of part or all of the periodontal ligament, resulting in fusion of root cementum and alveolar bone.
- Radicular hypsodont** – Subdivision of hypsodont dentition, sometimes called closed root, in which true roots erupt additional crown through most of life. These teeth eventually close their root apices and cease growth. As teeth are worn down, new crown emerges from the reserve or submerged crown of the teeth.
- Radiolucent** – Offering little or no resistance to the passage of X-rays.
- Radio-opaque** – Offering resistance to the passage of X-rays.
- Ramp** – Coloquial term, e.g., pathological exaggeration of distal upward slope of mandibular cheek teeth.
- Ramus** – The vertical ramus is the portion of the mandible that is covered by the masseter muscles and forms the angle of the jaw and temporomandibular joint. The horizontal ramus houses the cheek teeth.
- Ranula** – Salivary retention cyst (sialoceles) located under the tongue caused by blockage of the sublingual duct or gland.
- Rarefaction** – Loss of bone substance that creates an area of radio-opacity on radiographic examination.
- Rasping** – Floating of teeth.
- Recession** – Migration of the gingival crest in an apical direction.
- Recessive** – An allele that produces an effect on the phenotype only when present in a double form.
- Removal appliances** – Orthodontic devices designed to be easily and routinely removed and then reinserted.
- Reparative dentin (tertiary dentin)** – Localized formation of dentin in response to local trauma such as occlusal trauma or caries.
- Repulsion** – Exodontia by means of forces applied to the dental apices.
- Reserve crown** – The portion of the crown which is yet to erupt into the oral cavity.
- Resorption** – Physiologic removal of tissues or body products as of the root of deciduous teeth or of some alveolar process after the loss of the permanent teeth.
- Restorative dentistry** – Area of dentistry that is concerned with treatment, repair and conservation of teeth broken down through trauma or caries.
- Retro- (prefix)** – From behind, backwards.
- Retrognathism** – Anatomical relationship where the mandible lies in an excessively caudal/retrusive position in relation to the upper jaw. Veterinary, Overshot.
- Retarded eruption** – Delayed eruption of teeth from a variety of influences.
- Retrograde** – Reverse approach. In endodontics indicates root filling from an apical approach.
- Reversible pulpitis** – Inflammation of the pulp that can be resolved, returning the pulp to a healthy state.
- Rhinitis** – Inflammation of the mucous membrane lining of the nasal passage.
- Ridge** – A linear elevation. May be marginal, triangular, cusp, incisal, oblique or transverse.
- Root** – The enamel-free area at the apex of a tooth. That portion of the tooth normally embedded in the alveolar process and covered with or fully composed of cementum.
- Root bifurcation** – That point at which a root trunk divides into two separate branches.
- Root canal** – The apical opening(s) of the pulp chamber(s) of the tooth. These openings are wide in young teeth (open roots) but constrict due to secondary dentin deposition in older teeth.
- Root sliver** – Portion of root left in place after exodontia.
- Root resection** – Cutting off of a root but not its associated portion of crown.
- Root trifurcation** – That point at which a root trunk divides into three separate branches.
- Rostral (anterior)** – Toward the front of the body (e.g., toward the muzzle).
- Rostral hook** – Colloquial term for a focal overgrowth of the rostral aspect of the O6s (usually uppers in horse with overjet, but occasionally on lower O6s in horses with underjet).
- Rugae** – Small ridges of tissue extending laterally across the hard palate.
- Rule of dental succession** – No successional and deciduous precursor should be erupted simultaneously or in competition for the same dental arcade space at the same time.
- Sagittal** – Anatomical plane running parallel to the median (midline) plane (e.g., sagittal fracture of a cheek tooth through the infundibula).
- Salivary glands** – Glandular system secreting saliva, a serous and mucus-like fluid that assists in the lubrication and digestion of food.
- Salivary mucocele** – Localized collection of saliva in tissues other than a salivary gland or duct.
- Secondary dentin** – Normal physiologic dentin (both regular and irregular) formed throughout the pulp cavity following eruption.
- Secondary dentition** – Permanent dentition.
- Section** – The process of cutting; a division or segment of a part.
- Sedation** – Drug-induced calmed state, diminished physical activity and a reduced response to stimuli, where pain is not fully eliminated and an effective swallow reflex is maintained.
- Selenodont dentition** – The feature of having cheek teeth with cusps that connect to form a crescentic outline, quarter-moon or concavoconvex ridge pattern as in the even-toed hoofed animals (order Artiodactyla) except swine.

- Sequestrum** – A detached piece of necrotic bone that is devoid of its blood supply.
- Seven year hook** – Colloquial term for overgrowth of lateral corners of 103 and 203 erroneously believed to always occur at 7 years of age.
- Seroma** – Localized accumulation of serous exudate associated with surgical dead space.
- Sharpey's fibers** – The part of the periodontal ligament embedded in cementum or alveolar bone.
- Shed** – Term used for exfoliation of deciduous teeth.
- Shear mouth** – A wear disorder of cheek teeth where the angulations of the occlusal surfaces are increased (e.g., >45° to the horizontal plane).
- Shell teeth** – A hereditary and/or congenital disorder of teeth in which there is crown but little to no root development.
- Sialoceles** – Retention cyst of salivary fluids.
- Sialolith** – Salivary stone; calcifications found in salivary glands or ducts.
- Sinus** – Air cavity connected with the nasal cavity also means an epithelial lined tract between an area of suppuration and an epithelial surface.
- Sinusitis** – Inflammation of a paranasal sinus or sinuses that can be due to apical infections of caudal 4 maxillary cheek teeth as well as to non-dental causes such as primary infections, cysts or tumors.
- Slant mouth, slope mouth, diagonal bite** – A disorder of wear where the incisor occlusion surface angle deviates from horizontal (e.g., due to eating with only one side of the mouth), due to a cheek teeth disorder or wry nose.
- Smooth mouth** – Age-related dental attrition with loss of occlusal enamel of the clinical crowns.
- Soft palate** – Unsupported soft tissue that extends back from the hard palate free of the support of the palatine bone.
- Soft tissue** – Non-calcified tissues such as muscle, nerves, arteries, veins and connective tissue.
- Sow mouth, Monkey mouth, colloquial term** – Prognathism protruding mandible.
- Speculum** – Mechanical device used to hold the mouth open.
- Spreader** – Forceps used to separate cheek teeth for extraction.
- Squamous cell carcinoma (SCC)** – Malignant tumor of the squamous epithelium.
- Star, dental star** – The exposed secondary dentin-filled portion of the pulp chamber on the occlusal surface of the incisors is used in the estimation of age.
- Static occlusion** – Relationship of the teeth when the jaws are closed in centric occlusion.
- Steinmann pin** – Cylindrically shaped metal rod with threaded or trochar points used as an intramedullary splint in fracture repairs.
- Stellate reticulum** – Ectodermal derived middle layer of the enamel organ. It serves as a cushion for the developing enamel.
- Step mouth** – A cheek teeth row with one or more rectangular 'step-like' occlusal abnormalities. Usually due to loss of a tooth with overgrowth of its occlusal counterpart.
- Stomatitis** – Inflammation of the soft tissues of the oral cavity or mouth.
- Stomodeum** – Depression in the facial region of the embryo that is the beginning of the oral cavity; the primitive mouth.
- Sublingual caruncle** – Small elevation of soft tissue at the base of the lingual frenum that is the opening for the mandibular salivary duct.
- Sublingual fold** – Fold of tissue extending backward on either side of the floor of the mandible above the mylohyoid line in the canine region.
- Sublingual salivary gland** – Smaller of the major salivary glands.
- Subluxation** – Incomplete dislocation of a joint such as the temporomandibular joint or a tooth from its alveolus.
- Submandibular** – Referring to the region below the mandible; e.g., to a group of lymph nodes around the submandibular salivary gland.
- Submerged teeth** – Teeth covered by bone.
- Successional lamina** – An elongation of the primary tooth germ from which a permanent tooth will eventually take shape.
- Successional (succedaneous) teeth** – Permanent teeth that replace or succeed a deciduous counterpart, typically certain dihyodont incisors, cuspids or premolars.
- Sulcus** – Elongated valley in the surface of a tooth formed by the inclines of adjacent cusps or ridges that meet at an angle.
- Superior** – Indicating the relative position of a structure that is higher than others.
- Supernumerary roots** – Those roots beyond the normal complement of a tooth.
- Supernumerary teeth** – Those beyond the normal complement (extra).
- Suppurate** – To discharge pus.
- Supra- (prefix)** – Above.
- Supraeruption** – Eruption of a tooth beyond the occlusal plane.
- Symphysis** – The central rostral point of the mandible where the two parts of the hemimandibles join. This may remain a fibrous joint throughout life or it may ossify at birth.
- Synarthrosis** – Any immobile or fused joint that lacks a synovial capsule; it is usually formed by fibrous tissue, cartilage or a mixture of both.
- Tartar** – Calcified salivary deposits on clinical crowns. Calcium hydroxyapatite.
- Temporalis muscle** – Muscle of mastication arising from the temporal fossa and inserting on the coronoid process of the mandible to close the mandible.
- Temporary teeth** – The first set of temporary teeth that are shed at some point and replaced by permanent teeth.
- Temporomandibular joint (TMJ or jaw joint)** – The articulation of the mandible and temporal bones of the skull.
- Temporomandibular ligament** – Thickened part of the temporomandibular joint capsule on the lateral aspect.
- Teratoma** – Tumor or group of tumors composed of tissues that would not normally occur at that site. Derived from germ cells and often containing teeth or hair.
- Tertiary dentin** – See reparative dentin.
- Tetracycline stain** – Intrinsic grey, green, yellow or brown discoloration of the dentin and enamel caused by systemic treatment with a tetracycline-based antibiotic at the time of development of the tooth.
- Thecodont** – The feature of having teeth that are firmly set in sockets.
- Theory of periodontal ligament force** – Eruption theory that the periodontal ligaments, forces necessary for occlusal maintenance also contributes to eruption.
- tomy (suffix)** – Surgical cutting of a part.
- Tomes process (Tomes fibers)** – Ameloblast processes.
- Tongue** – A mobile prehensile structure of the oral cavity used for grooming and intake of food and fluids.
- Tooth** – A calcified structure containing dentin attached to the jaws of vertebrates occurring in or at the mouth; or in the alimentary canal of some invertebrates.
- Tooth bud** – The formative structure of a tooth in the dental follicle.
- Tooth eruption** – Emergence and movement of the crown of the tooth into the oral cavity.
- Tooth germ** – Soft tissue that develops into a tooth.

Tooth migration – Movement of a tooth through the bone and gingival tissue.

Tooth resection – Cutting off of a portion of the crown with or without its associated root structure.

Trabeculae – Interlacing meshwork that makes up the cancellous bony framework.

Transverse – Across a longitudinal anatomical plane or direction from medial to lateral (i.e., lingual to buccal).

Trephination – Process of making an opening into a bone with a trephine (e.g., for surgical exposure of the sinuses or repulsion of a tooth).

Trephine – To perforate with a trephine (*see* trephination). A cylindrical saw for cutting a circular piece of bone out of a skull.

Triadan nomenclature – System for the precise numbering of teeth and their position. Modified and applied to many species.

Trifurcation – Division of three tooth roots at their point of junction with the root trunk.

Trigeminal nerve – Cranial nerve V that innervates many of the muscles of mastication and is sensory for much of the head region.

True temporomandibular joint ankylosis

– Inhibited jaw movement due to a bony union across the temporomandibular joint surface.

Tushes, tusks, colloquial term (*see* canines).

Twinning disorder – Dentistry. Condition in which there has been a complete cleavage of the splitting germination bud with the extra tooth being a mirror image of the original, not a separate tooth bud.

Twitch – A loop of cord attached to a stick used to control horses during veterinary examination or treatment through pinching the upper lip by tightening the cord with the twisting action of the stick.

Ulcer – Break in the skin or mucous membrane resulting in the exposure of deeper structures.

Underbite, Underjet, Undershot, Sow mouth – Protruding mandible.

Ventral – Anatomically, that which is below (e.g., opposite of dorsal).

Vestibule – Space between the lips or cheeks and the teeth.

Vestige, vestigial – The remnant of a structure that functioned in a precursor of that species (e.g., the wolf teeth of horses, canine teeth in mares).

Vice – A bad habit.

Vincent's infection (Acute necrotizing gingivitis, Trench mouth) – Fusiform and spirochete (*Borrelia vincentii*) gum infection in man.

Vital tooth – Tooth or pulp tissue with intact innervation and vascular supply.

Vomer – Bone that forms the lower part of the nasal septum.

Wave mouth – An acquired disorder of wear of the cheek teeth where their occlusal surfaces have a wavelike appearance in a rostrocaudal direction.

Wry nose – Campylorhinus lateralis.

Wolf teeth (Triadan 105, 205, 305, 405) – Vestigial teeth in the horse; the first premolar; small teeth rostral to the second premolar.

Wry mouth – Condition in which one of the four jaw quadrants is grossly out of proportion to the other three causing a facial deviation from the midline.

Zygomatic arch – Arch of bone on the side of the face or skull formed by the zygomatic bone and temporal bone.

Zygomatic bone – Bone that forms the cheek area.

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